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ORIGINAL ARTICLES.

I.—Sedgwick Museum Notes.

A New Fossil from Girvan.

By F. R. Cowper Reed, M.A., F.G.S.

(PLATE XV.)

Helminthochiton thraivensis, sp. nov. (Plate XV.)

Description. Body elongated, narrow, composed of a longitudinal series of eight imbricating plates, and marginal girdle (?) of spicules.

First or head-plate transversely subcircular, broader than long, smallest of the series; about two-thirds the length of second plate; surface gently convex, very weakly carinated in posterior median part; posterior edge arched back, slightly angulated and projecting; inferior surface with submarginal concentric thickening.

Second to seventh plates of nearly equal size and shape, transversely trapezoidal in outline, about twice as wide as long, bent down strongly on each side of median axial line at angle of about 90°; imbricating backwards in middle. Anterior margin broadly emarginate, being excavated by shallow rounded median sinus; lateral portions of anterior margin arched forward as rounded lobes, with outer (=inferior) angle broadly rounded and passing into inferior margin, which is nearly straight and parallel to axial line. Posterior margin angulated in middle line, projecting backwards as bluntly pointed broad lobe slightly overlapping succeeding plate behind. Posterior and inferior margins meet at obtuse angles, or in seventh plate at right angles. Surface of plates in middle portion of body marked by pair of faint shallow depressions diverging anteriorly and broadening to anterior outer angles. Middle portion of plates internally thickened in a transverse direction, so as to make internal casts somewhat saddle-shaped. Posterior margin of plates furnished internally with narrow thickening close to edge, with several much finer parallel linear thickenings behind it. Upper surface of second to seventh plates ornamented with two (or sometimes more) strong regular concentric striæ parallel to anterior and outer edges of plates, one being situated usually at about one-fourth the length and the other at one-half the length, with finer concentric striæ between them.

Eighth or terminal plate smaller, less strongly bent along middle, gently convex, semi-elliptical in shape, rounded behind, with submarginal concentric thickening around anterior and outer edges on inferior surface.

Surface of all eight plates covered with closely set pores (with a few larger ones interspersed) arranged concentrically in a somewhat obscure manner between the finer striæ near lateral margins.

Girdle covered with densely felted mass of small spicules.

Dimensions.		mm.
Length of first (anterior) plate	about	6 to 7
Length of other plates	,,	12 ,, 13
Width of first plate	,,	10 ,, 12
Width of other plates	,,	22 ,, 24
Estimated length of whole body		85 ,, 90

Horizon and Locality. Starfish Bed (Upper Bala), Drummuck Group: Thraive Glen, Girvan. (Mrs. Gray's Collection.)

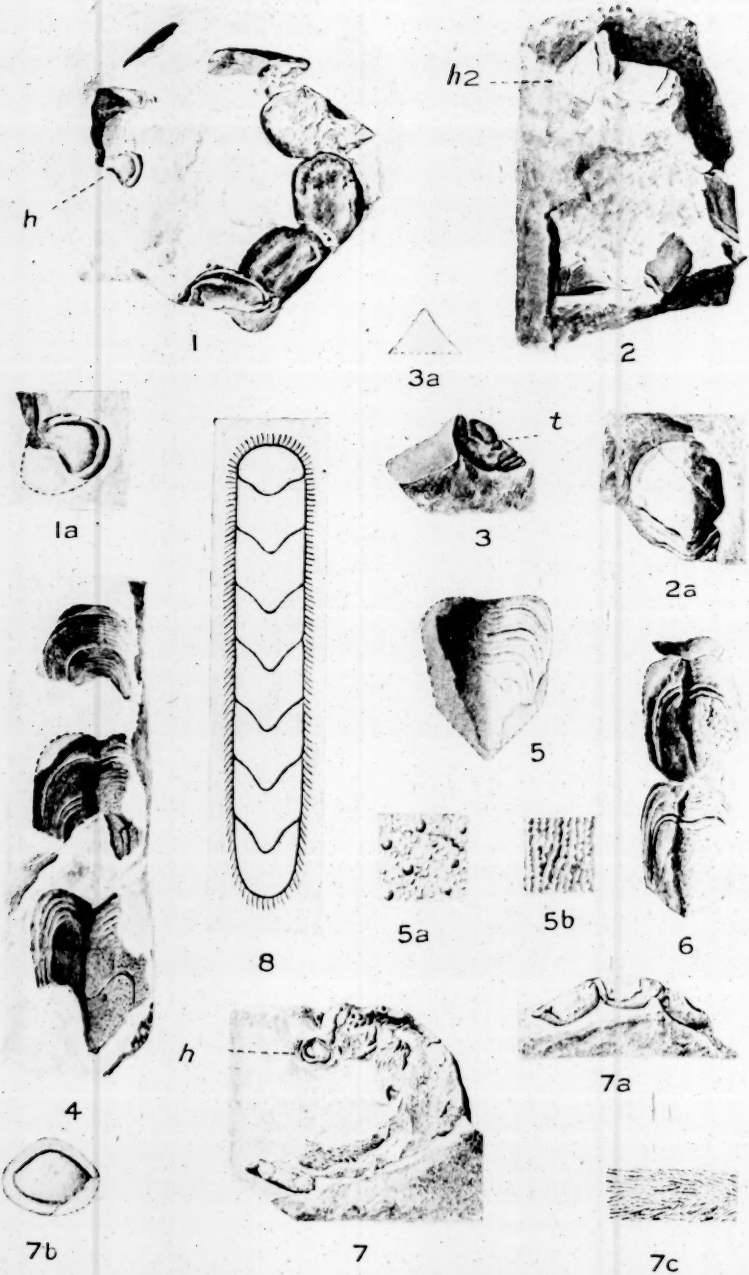
Remarks. There are several more or less perfect specimens of this new species in Mrs. Gray's Collection; one shows the whole eight plates in serial position, though they are not all perfect and most are in the condition of internal casts with portions of the external impressions of the plates here and there preserved. In all cases the shell is absent, and a cavity represents the space which it occupied before it decayed or was dissolved and removed. Two other specimens possess the first plate followed by several others in order, and there are examples of two or more associated middle plates.

Two nearly complete specimens of the whole mollusc exhibit a mass of spicules partly filling up the cavity of the body for its whole length and slightly extending below and outside the inferior margins of the plates, suggesting that the 'girdle' was dependent or incurved on each side instead of horizontally extended. The spicules occur as hollow casts in a densely felted mass, and must be interpreted as of the same nature as those developed round the marginal girdle of some living species of *Chiton*.

The minutely punctate or poriferous condition of the plates is clearly seen with a hand-lens in all the external impressions, and from the fact that the surface of the internal casts also shows a similar granular appearance, it may be concluded that the pores pierced the shell-substance. If this interpretation is correct, we may probably regard the pores as corresponding to the 'micropores' and 'megalopores' in living forms through which the network of nerves ('aesthetes') reach the sense organs on the outer surface such as Moseley[1] and many later zoologists[2] have described.

According to Fischer's[3] classification this new species should be placed in the subgenus *Eochiton* of his genus *Holochiton*, Plate (op. cit., p. 384); he considers that all the Palæozoic *Chitons* belong to the *Lepidopleurus*-stage of the group. The nearest affinities of the Girvan form are with *Helminthochiton Griffithi*, Salter,[4] which it much resembles in general shape and proportions. McCoy[5] in his figure and description of the latter species reversed its position, his cephalic plate being in reality

[1] Moseley, Ann. Mag. Nat. Hist. (5), xiv, p. 141, 1884.
[2] L. H. Plate, Zool. Jahrb., Suppl. v (1901), Th. C., p. 498, and references.
[3] Fischer, *Manuel de Conchyl.*, p. 877, 1887.
[4] Salter, Q.J.G.S., vol. iii, p. 48, fig. 6, 1847.
[5] McCoy, *Syn. Silur. Foss. Ireland*, p. 71, pl. v, figs. 5*a–c*.



T. A. Brock del.

Helminthochiton thraicensis, sp. nov.

the terminal plate, so that the other plates of the body are, as in the Girvan form, emarginate in front instead of behind as he described.

H. Grayiæ (Woodward)[1] is a much more slender and elongated form, and the coarse ornamentation of the plates is quite different, but in some specimens recently found by Mrs. Gray there are indistinct indications that the shell was minutely perforate as in *Hel. thraivensis*.

EXPLANATION OF PLATE XV.

FIG.

1. *Helminthochiton thraivensis*, sp. nov. Side view of internal cast of complete individual, showing the eight plates in position. Nat. size. *h* = head-plate.
1*a*. Ditto. Head-plate of same specimen. × 2.
2. Ditto. Internal cast of the five anterior plates of another specimen. Nat. size.
2*a*. Ditto. Second plate (*h* 2) of same specimen. × 2.
3. Ditto. Side view of internal cast of the two posterior plates of another specimen. Nat. size. *t* = terminal plate.
3*a*. Ditto. Transverse vertical section of same specimen, showing axial bending of plates. Nat. size.
4. Ditto. External impression of three successive plates, showing anterior emargination. × 2.
5. Ditto. External impression of another plate, showing general shape. × 2.
5*a*. Ditto. Portion of surface of adjoining plate, showing large and small pits. × 6.
5*b*. Ditto. Portion of ditto near margin, showing concentric arrangement. × 6.
6. Ditto. External impression of two other plates. × 2.
7. Ditto. Natural longitudinal vertical section of complete individual, showing mass of spicules. Nat. size. *h* = head-plate.
7*a*. Ditto. Side view of internal cast of three successive plates of same specimen. Nat. size.
7*b*. Ditto. Internal cast of head-plate of same specimen, viewed from above. × 3.
7*c*. Ditto. Portion of spicular mass of same specimen. × 3.
8. Ditto. Diagrammatic restoration of complete individual.

N.B. All the specimens come from the Starfish Bed (Drummuck Group), Thraive Glen, Girvan, and are in Mrs. Gray's Collection.

II.—On Dedolomitization.

By T. Crook, A.R.C.Sc. (Dublin), F.G.S., Scientific and Technical Department, Imperial Institute.

IT is a noteworthy feature of the most ancient crystalline limestones that they are generally dolomitic, or at any rate frequently so. They often consist of practically pure dolomite; whilst associated with this in some cases is pure crystalline magnesite,[2] which is very liable to be mistaken for saccharoidal dolomite.

Crystalline dolomites, dolomitic limestones, and their dedolomitized equivalents have a world-wide distribution among the usually much-metamorphosed pre-Cambrian rocks. In North America they are well

[1] Woodward, Geol. Mag., Dec. III, Vol. II, p. 352, Pl. IX, Figs. 7–10, 1885; Reed, ibid., Dec. V, Vol. IV, p. 113, Pl. IV, Fig. 12, 1907.

[2] Such crystalline magnesite occurs in Ceylon, as at Randeniya, Wellawaya. It occurs also in various parts of North America (see Dana's *System of Mineralogy*, 6th ed., p. 275) and elsewhere.

represented in the widespread pre-Cambrian rocks of Canada, and they also occur in the United States. In India and Ceylon they occur freely among the rocks of the fundamental complex. In Africa they are met with in the ancient and highly metamorphosed basement rocks of Nigeria, Rhodesia, Nyasaland, Natal, and other areas. In Britain, highly metamorphosed dolomites of Cambrian age occur in North-West Scotland, and others of uncertain age are also met with among the rocks of the Dalradian complex.

There appear to be very few, if any, exceptions to the rule that these ancient dolomitic rocks, especially those of the pre-Cambrian, have been thermally metamorphosed. The characteristic feature of this metamorphism is the production of secondary minerals in which magnesia plays a supreme part. Very often, indeed, lime does not enter at all into these secondary minerals, e.g. olivine, serpentine, mica (phlogopite or biotite, generally the former), periclase, brucite, spinel, and chondrodite.[1] In tremolite, which is fairly common as a secondary silicate in these rocks, magnesia predominates over lime, whilst in diopside magnesia and lime play equally important parts. It is of interest to note that picroilmenite occurs as a constituent of metamorphosed dolomite in Ceylon, associated with forsterite, phlogopite, and spinel. In all probability geikielite occurs in the same way.

Wollastonite, idocrase, and garnet (andradite and grossularite), which are common as secondary minerals in non-dolomitic crystalline limestone, are notable for their absence, at least as a rule, in metamorphosed dolomites; and it seems, indeed, highly probable that they cannot develop as the result of the direct thermal metamorphism of dolomite.

The production of secondary magnesian minerals, or minerals in which magnesium predominates over calcium, in thermally metamorphosed dolomite, necessitates the formation of calcite, as has been shown by Teall.[2] In those portions of the rock where sufficient silica was present, dedolomitization may be complete, or almost complete, and in such a case a rock may be produced consisting essentially of forsterite embedded in calcite, with very little residual dolomite. The forsterite marbles of Sutherland and Skye described by Teall[3] and Harker[4] afford examples of this type.

Hatch & Rastall have described a unique and extremely interesting case of the partial metamorphism of a lump of granite in dolomite, in which the inner reaction zone showed complete dedolomitization, accompanied by the formation of olivine, spinel, and brown phlogopite.[5] It appears, however, that dedolomitization so complete as this, in

[1] It is convenient to use the name chondrodite in a general sense for the members of the humite series when dealing with scattered granules in these rocks, since it is not practicable to identify any given irregular small grain with safety as belonging to any particular member of the series.

[2] See particularly *The Geological Structure of the North-West Highlands* (Memoirs of the Geological Survey of Great Britain), pp. 453–62, 1907.

[3] Loc. cit.

[4] *The Tertiary Igneous Rocks of Skye* (Mem. Geol. Surv.), pp. 144–51, 1904.

[5] Q.J.G.S., vol. lxvi, p. 507, 1910.

which the secondary magnesium minerals are left embedded in calcite, is comparatively rare. Usually the change is much less complete, and then the rule seems to be that the secondary magnesium minerals are embedded in dolomite and not in calcite.

Two specimens which serve as good examples of this have been examined by the writer and are worthy of description—one a forsterite-phlogopite marble from Peradeniya, Ceylon, the other a chondrodite marble from Verona, Ontario, Canada. In both cases the texture developed as a consequence of thermal metamorphism appears to have persisted in an undisturbed condition.

The Ceylon specimen[1] is one of massive coarsely crystalline dolomite, traversed by a band of secondary silicates consisting almost wholly of forsterite in the form of small greyish and rounded grains. Phlogopite is also present, but the amount is very small. Spinel, which is frequently present in Ceylon dolomites as a product of metamorphism, appears to be absent in this particular case. On either side of the forsterite band the rock consists of fairly pure dolomite, with only here and there a microscopic patch of calcite, and a few scattered granules of forsterite, which are embedded, not in the calcite, but in the dolomite. The carbonate substance of the forsterite

Fig. 1. Metamorphosed dolomite, from Peradeniya, Ceylon; showing forsterite in dolomite. Stippled portion represents calcite which was stained by the Lemberg solution. × 15.

band itself is largely but not completely dedolomitized; and even here, where the grains of forsterite are thickly set, they are never exclusively surrounded by calcite, and are generally embedded in dolomite (see Fig. 1). Judging from the relative amounts of calcite and forsterite present, it seems tolerably certain that the calcite present in the specimen has arisen entirely by dedolomitization, and that before metamorphism the carbonate consisted wholly of dolomite.

[1] This is a specimen of the Ceylon Mineral Survey collection at the Imperial Institute.

An examination of numerous sections of this Ceylon specimen showed a plentiful development of forsterite grains surrounded by coronas of dolomite, these being set in a matrix of calcite. The coronas are sometimes complete, sometimes broken, and often show attachment to adjacent patches of dolomite (Fig. 1). Here and there is seen a tendency to a linear arrangement, the adjacent coronas of dolomite coalescing in a manner which suggests eozoonal structure.

The secondary calcite contains numerous inclusions of dolomite. These inclusions are sometimes arranged in parallel layers (Fig. 1). Instead of parallel layers we may get a micropegmatite-like intergrowth[1] of the two minerals, or the dolomite may be scattered in the calcite in disconnected granules.

A feature of special note observed in the sections is that the streaks of dolomite intergrown with the calcite are sometimes connected with the dolomite coronas in such a way as to suggest that they served as channels along which magnesia was supplied to the coronas during the growth of the enclosed grain of forsterite.

The specimen of chondrodite marble from Ontario differs markedly from the Ceylon specimens just described in that the original rock was clearly a dolomitic limestone rather than a true dolomite rock, the amount of magnesia being small compared with that of lime. Here again, however, the secondary minerals which have been produced by metamorphism are free from lime (excepting calcite), the minerals observed being chondrodite, spinel, phlogopite, graphite, and pyrrhotite. As in the forsterite rock from Ceylon, these secondary minerals show a decided preference to be embedded in dolomite, though the amount of dolomite present is comparatively small. This is particularly the case with the grains of chondrodite. In the sections examined, each of the numerous grains of chondrodite had its corona of dolomite (see Fig. 2). Here again, in addition to the coronas, the sections show scattered grains and patches of dolomite in the calcitic matrix; and the simultaneous extinction of neighbouring patches of this dolomite, in some cases, suggests that they are portions of an anastomosing growth of dolomite. A pronounced feature in this specimen is the turbidity of the calcite as compared with the dolomite; this is a point which has been emphasized by previous workers who have described similar rocks.

Another specimen examined was kindly supplied by Dr. Hatch, from the outer ophicalcite zone of the Port Shepstone occurrence dealt with in the paper by Hatch & Rastall already referred to. This specimen is one of critical importance, owing to the definiteness of certain of the conditions of metamorphism in that particular case. As previously mentioned, it was shown by these authors that the inner reaction zone in the Port Shepstone instance was marked by practically complete dedolomitization. In the outer zone, however, one would expect the change to be far from complete; and the examination of a specimen of the ophicalcite proves this to be the case. Moreover, the coronal layers of dolomite around the grains of serpentine in this ophicalcite

[1] These peculiar intergrowths of dolomite in calcite appear to be identical with those described and figured by Coomaraswamy ("Crystalline Limestones of Ceylon": Q.J.G.S., vol. lviii, p. 412, 1902).

are better developed than in any of the other specimens which the writer has examined. The turbidity of the calcite as compared with the dolomite is a pronounced feature in the Port Shepstone specimen.

Several other specimens of metamorphosed dolomite from various localities, including Glenelg and Iona in Scotland, exhibit the same tendency to the development of coronas of dolomite around the grains of the secondary magnesium minerals (olivine and serpentine). The Iona specimen examined by the writer is of considerable interest as showing a streakiness or somewhat foliated character, arising from pressure-flow subsequent to thermal metamorphism. This pressure-flow has been accompanied by partial destruction of the enclosing shells of dolomite; but there can be no doubt that the texture originally produced by thermal metamorphism in this case was essentially similar to that of the Ceylon and Natal rocks described above.

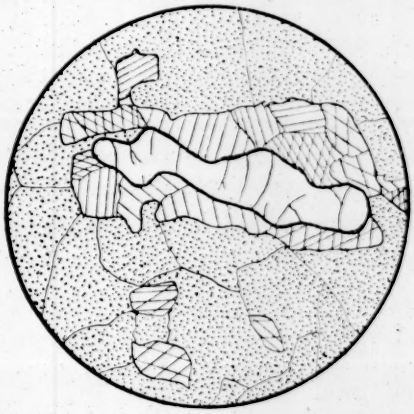


FIG. 2. Metamorphosed dolomitic limestone, Verona, Ontario; showing chondrodite with an almost complete corona of dolomite. Stippled portion calcite. × 12.

Typical 'Eozoon' seems to afford a good example of a metamorphosed dolomite in which the dedolomitization is almost complete. Very little dolomite remains behind in the writer's specimen; this is sometimes in the form of scattered grains in the calcite matrix, but more commonly it forms partial coronas around the coalesced serpentine grains.

The petrography of 'Eozoon' strongly suggests that it was formerly a forsterite marble. Adams & Barlow, however, writing apparently with reference to the 'Laurentian' limestones of North America as a whole, state that "Olivine has never been found in these limestones; nor is there any reason to believe that it ever exists or ever did exist in them".[1] They hold the view that the serpentine in all cases has

[1] *Geology of the Haliburton and Bancroft Areas, Province of Ontario.* F. D. Adams & A. E. Barlow, Memoir, No. 6, Department of Mines, Canada, p. 214, 1910.

been derived from pyroxene, a view which many will find it difficult to accept.

In making the above observations, the calcite and dolomite were distinguished from one another by staining with the well-known Lemberg solution—an aqueous solution of logwood and aluminium chloride. This is quite the safest means of discriminating between calcite and dolomite in rock slices, and never fails to give satisfactory results when properly managed. One should remember, however, that magnesite acts like dolomite in this respect, and remains unstained. The suspicion that some of the unstained portions of the slides might be magnesite led the writer to make density tests in several cases; but the results indicated that, in the specimens tested, the unstained material was dolomite.

To summarize the foregoing remarks, it appears from the specimens examined by the writer that one may represent the process of dedolomitization in three stages, viz.:—

1. Where the amount of silica is small we may get the magnesium silicates, etc., embedded in dolomite, with no calcite in their immediate vicinity. The calcite in such a case may be seen scattered in small patches in the dolomite, but noticeably remote from the secondary magnesium minerals; and in some cases we may get sections showing a considerable development of serpentine with practically no calcite.

2. A more advanced stage in dedolomitization is represented by the condition in which dolomite forms coronas round the grains of the secondary magnesium minerals. The calcitic matrix at this stage is usually interspersed with dolomite, which may be in the form of scattered granules or connected intergrowths. If the rock is coarse-grained the dolomite may be in the form of platy intergrowths showing parallel bands in section; and in such a case there appears to be a connexion between the platy intergrowths of dolomite and the dolomite coronas surrounding the grains of the secondary magnesium minerals.

3. In the most advanced stage, where the amount of silica has been sufficient to combine with the whole or almost the whole of the magnesia of the dolomite, the secondary magnesium minerals are left embedded in calcite. Any small amount of residual dolomite present in such a case may be in the form of scattered granules, or groups of granules, in the calcitic matrix; or may be left as broken remnants of the coronas around the grains of the secondary minerals.

The facts thus summarized are of considerable interest, partly as indicating the prevalence in thermally metamorphosed dolomites of certain textural features which have not been hitherto described, and partly also as throwing some light on the process of dedolomitization. There can be little or no doubt that such minerals as olivine, serpentine, chondrodite, phlogopite, spinel, and other magnesium minerals characteristic of crystalline dolomites and dolomitic limestones, are as a rule secondary to the dolomite. At least this has been clearly proved in many cases. There is, moreover, a close similarity between the facts of paragenesis and texture in all cases; and there seems to be no ground for Fermor's inference[1] that the dolomite and

[1] "Petrology of Chhindwára": Rec. Geol. Surv. Ind., vol. xxxiii, pt. iii, 1906.

calcite, in the rocks described by him, have arisen by the alteration of silicates under the influence of carbon dioxide.

It seems equally clear, however, that the process of dedolomitization is not quite so simple as has been supposed, and its explanation seems to call for still more facts.

III.—The Granite Mass of Foxdale, Isle of Man: with some notes on Dendritic Markings in Microgranite Dykes.

By William C. Simmons, B.Sc., A.R.C.S.

(MAP, PLATE XVI.)

THE mining village of Foxdale, situate a little towards the southern end of the north-east to south-west central trend-line of the Isle of Man, lies just north of the barren heath-covered hill called "Stoney Mountain". On the 6 inch Ordnance Survey Map the northern part of this hill is called Granite Mountain and the southern portion Windy Common. The whole forms a long, regularly sloped hill with its greatest length—about 2 miles—approximately north and south. Though of small altitude its singular barrenness makes it conspicuous in a moderately well-cultivated district. To the west South Barrule and the Barrule Slate Quarries rise considerably above it, though on the other sides the ground slopes gently off to more distant hills.

The granite occupies only about a third of the whole area of Stoney Mountain, and that all at the northern extremity. A small isolated exposure of the granite occurs a short distance to the east, near the little village of Eairy. These granite masses are intrusive into the Manx Slate Series, which have been in places considerably altered.

In both the larger Foxdale granite mass and the latter smaller one thick veins of quartz and coarse pegmatite occur. Sometimes these quartz veins, then resembling dykes, are found outside the granite intruded into the country rock. Lastly there are the characteristic microgranite dykes, associated with the granite mass and usually intruded in the slates with a N.E.–S.W. trend.

The field relations of the "Granite and its Elvans" are discussed in the Survey memoir of the Isle of Man (G. W. Lamplugh, 1903), to which also notes on the petrology of the rocks by Professor Watts are appended. Much quarrying has since been carried on in the quartz veins for silica, and consequently better sections can now be seen. It seems that a few further notes upon these very peculiar 'quartz dykes' may not be out of place.

Mr. Lomas[1] has described some of the veins and gives a rough description of their distribution, arriving at the conclusion that both those in the granite and those in the country rock are of igneous origin. Beyond brief notices in the Survey memoir and elsewhere, and a short description by Mr. A. Harker,[2] little other literature on the matter has come to hand.

[1] Lomas, Geol. Mag., 1903, pp. 34–6.

[2] A. Harker, *Naturalist* (Leeds), March, 1894 (note). Id., "Grainsgill Greisen": Q.J.G.S., vol. li, p. 143.

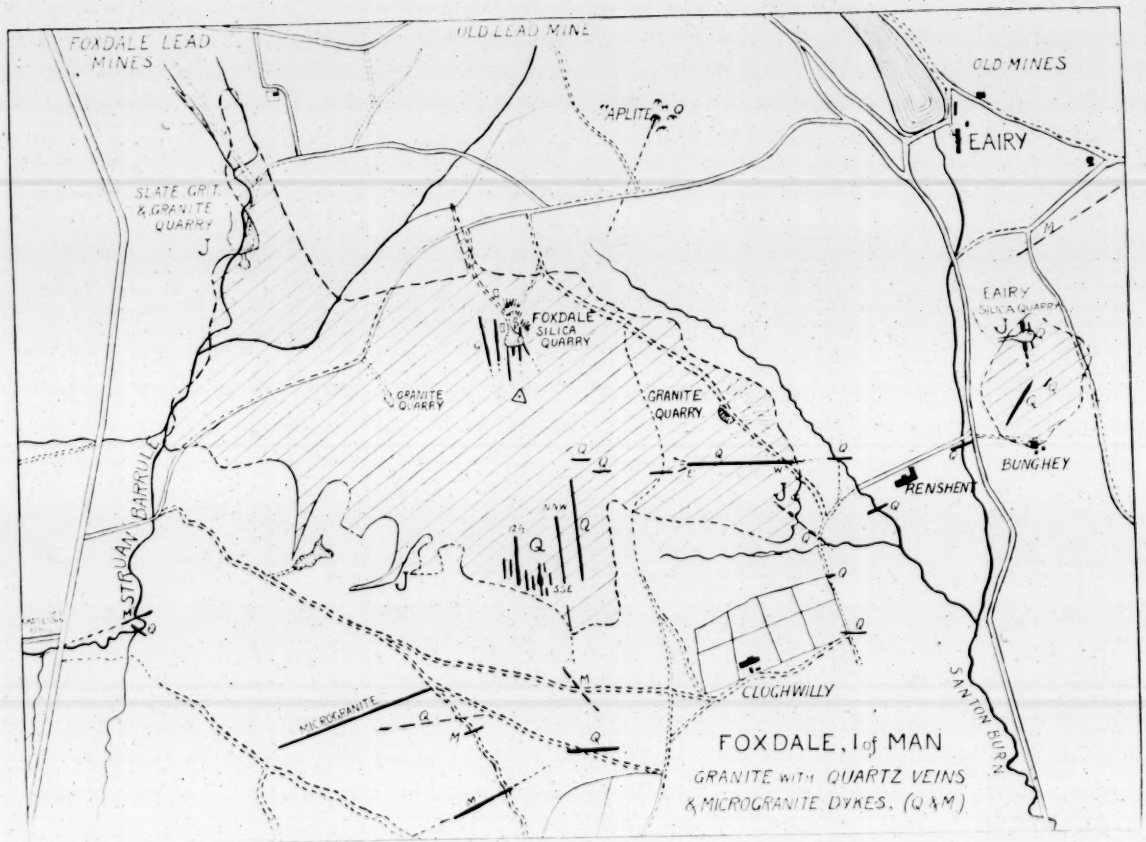
Description of the Map. (Plate XVI.)

The map is on the scale of 4 inches to 1 mile, and shows the shape of the outcrop of the granite mass. At the points marked J actual junctions between the granite and the altered country rock are exposed. Elsewhere the boundary is lined or dotted according as to whether the mapping is certain or only probable.

In the quarry below the Foxdale lead-mines (see Map, "slate, grit, and granite quarry") a good junction is seen. Between the granite and the slate a thick vertical strip of finer-grained granite occurs, which is continuous with a fine microgranite dyke on the other side of the quarry.

Tracing the boundary south it can be seen to cross the stream (Struan Barrule) in several places and then to sweep east up the hill till we come to the apophyses marked on the map. These apophyses can be easily traced round the slate quarry, and at J is the slickensided junction with a dip of 30° (approx.) to the south-east under the slates, described in the Survey memoir. The granite of the apophyses is very fine-grained, or rather, contains strips of fine-grained microgranite. Further east the boundary is somewhat obscured by bog, but is fairly clear as one approaches the farmstead of Renshent, where a junction with highly altered slates is seen in a little cutting. Then no other junctions are seen till the Foxdale Silica Quarry is reached (see Section, Fig. 2, p. 349), north of which a small apophysis runs out from the granite (Survey memoir, p. 165).

So far we are more or less in agreement with the Survey 1 inch map, but on this map the quartz veins are not shown. There may be other veins besides those shown upon the accompanying map, as there is considerable peat and boulder-drift, but the main veins are indicated as far as they can be traced. It will be noticed that these veins lie in three sets, somewhat radial, or approximately in two directions, viz., north and south, east and west. In the Foxdale Silica Quarry (Fig. 2, p. 349)—"the Spar Quarry"—there are several thick veins to be later described. The veins occur in greatest number to the south of the intrusion and several of them are 12 feet thick, while one for a short distance attains a thickness of 18 feet, but soon thins out to 2 or 3 feet on either side. Opposite Renshent (see Map, Plate XVI) a vein 12 feet in maximum thickness can be traced some way up the 'mountain', and it seems as though it is continuous with the vein outcropping in the stream to the east, but there is boggy ground between. The Eairy granite mass to the east is a smaller mass in every way similar to the main outcrop. Between the two outcrops the slates and grits are much altered and are exposed in the little stream. In the Survey memoir the question is raised as to whether this Eairy mass is connected with the Foxdale mass below or as to whether it is merely a portion of the latter that has been thrust into its present position. Since the Survey visited the spot a section of the junction of the granite with the slate has been exposed by quarrying in the Eairy mass for silica, and there seems evidence here that the mass is *in situ* and is a similar and connected intrusion. (See description of Section, Fig. 3, in Eairy Silica Quarry.)


FOXDALE LEAD MINES
OLD LEAD MINE
OLD MINES
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EAIRY
SLATE GR.T & GRANITE QUARRY
FOXDALE SILICA QUARRY
EAIRY SILICA QUARRY
GRANITE QUARRY
GRANITE QUARRY
BUNGHEY
RENSHENT
CLOGHWILLY
SANTON BURN
MICROGRANITE
FOXDALE, I of MAN
GRANITE WITH QUARTZ VEINS & MICROGRANITE DYKES. (Q & M.)

Quartz and pegmatite veins occur in this mass also. The boundaries, except at the above-mentioned junction, are nowhere seen owing to thick boulder-drift. The distribution of the heath and boulders and the levels give the probable mapping.

The Quartz Veins.

The Foxdale Silica Quarry (see Map, Plate XVI, and Section, Fig. 2, p. 349).

Judging from the surface outcrops of the pegmatite veins an observer sees little to lead him to any other conclusion than that these consist simply of walls of white quartz spangled in places with mica, which project through the peat among the granite blocks and can be traced for a considerable distance up the mountain. They seem on the surface to be simple dykes; but when exposed in section in the quarries the apparent simplicity gives way to a complexity at first confusing, but which a little consideration easily elucidates. In the quarry the 'dykes' are seen to be thick, nearly upright veins which send out offshoots into the granite, dipping up at a high angle. The figure gives a diagrammatic representation of the facts (Fig. 2). The quarry face is irregular, and in the sketch the whole is brought to one plane. The main veins are the two upright ones to the right of the figure. The larger does not reach up to the surface, and it sends offshoots to the right which have a high dip into the quarry face. The irregular surface is here largely due to irregularity in the quarry face combined with this high dip. To the left are three veins with a dip of approximately 45° to the west, and farther out a larger vein is seen which includes parts of the granite. The whole of the material between the veins is a rather coarse-grained muscovite granite. The quartz locally passes into pegmatite, which consists essentially of quartz with spangles and matted masses of pale-bronze coloured mica, which is of the same type as the mica of the granite.

Several interesting things are to be observed in this quarry. In one case (not shown in the Figure) a vein occurs which is practically upright and has on its sides a felted mass of pale-bronze mica between it and the granite. This selvage is about half an inch in thickness and could be traced for two or three yards. On the west side of the quarry a vein occurs which can be seen running up the hill for some distance (see Map). In a little cutting outside the quarry the whole of the vein for a short distance has been cleaned out, and the side walls remain perfectly smooth and upright. These walls consist of granite with a coating of a mixture of quartz and orthoclase felspar, half an inch and less in thickness. This is a peculiar selvage; the felspar is idiomorphic and the quartz more or less allotriomorphic though with parallel growth, and it is quite water-clear. The selvages are of importance in considering the origin of the quartz veins.

Another interesting fact here is the occurrence of 'lochs' in parts of the quartz veins. Large drusy cavities occur which are lined with good quartz crystals, in continuity with the quartz of the vein, and usually therefore there is a tendency to a parallel growth in them. Rarely the crystals are water-clear, but usually they are milk-white, like the veins themselves (due to inclusions, see Mr. Lomas' paper). These

druses, called 'lochs' by the quarrymen, are said by them often to contain water. Now the veins are much jointed and cracked, and after breaking open many blocks with druses we succeeded in finding one or two containing water, but which evidently had filtered in along the cracks, as attested by the iron-stained path taken by it. All the quartz veins in the Foxdale Silica Quarry are of one type. They consist of almost pure quartz crystallized on a large scale, sometimes with flakes of mica. These are the quartz veins proper. At Eairy Quarry we get also fine-grained quartz-mosaics, forming the vein instead of the large crystals seen at Foxdale Quarry.

The Eairy Quarry (see Map, Plate XVI, and Section, Fig. 3, p. 349).

It is here that a junction of the slate with the granites may be seen, and here are thick pegmatite and quartz veins, with microgranite and granite giving an interesting section. The Figure (Fig. 3) explains itself. There is here much glacial drift covering the rocks, giving in one case quite a peculiar fold to the fragments.

The junction of the slates with the granite is quite a normal one, and the former are altered to mica schists and phyllites close to the granite. If the Eairy granite mass has been thrust off from the larger Foxdale mass, then the junction and slates too must have been subjected to the thrust. This does not seem probable, but evidence is wanted to prove that the slates are continuous with the main mass of the country rock. It should be noted that in few places are the slates so altered as between the two outcrops of granite. In the quarry section, next to the junction, a thick mass of jointed pegmatite cuts across the granite and slates (Fig. 3, *P*, *P*). It consists of quartz with large spangles of mica. The joint planes run at a steep angle to each other, and between the planes in two or three places a deposit of brown powdery limonite occurs, in one case as much as a foot thick, but shading off rapidly upwards. This is bounded further in the quarry by several faults with quartz and microgranite between them. These faults are also full of limonite. The mass of microgranite next shown is a fine granite very similar to the normal microgranite dykes associated with the granite. It is in parts stained by infiltered limonite and hæmatite along the joints which make dendritic markings, comparable with those found on Windy Common to the south, mentioned later.

A thick vein of quartz follows with a dip of about 75° to the east. This sends an offshoot into the microgranite. Lastly, there is another quartz vein separated from the former on both sides of the quarry by a wall of granite, but they run together through the granite in the centre. These last two veins of quartz contain little mica, but are much stained by infiltered iron-bearing water to yellow, brown, and red.

Mr. Harker describes the Foxdale granite thus: "It consists of quartz, microcline, an acid plagioclase, muscovite, subordinate biotite, and little crystals of garnet and zircon. In the marginal part of the intrusion are developed bands and masses of pegmatite, thick veins and bands of greisen, and finally quartz veins containing only local aggregations of white mica or bordered by a narrow seam rich in that

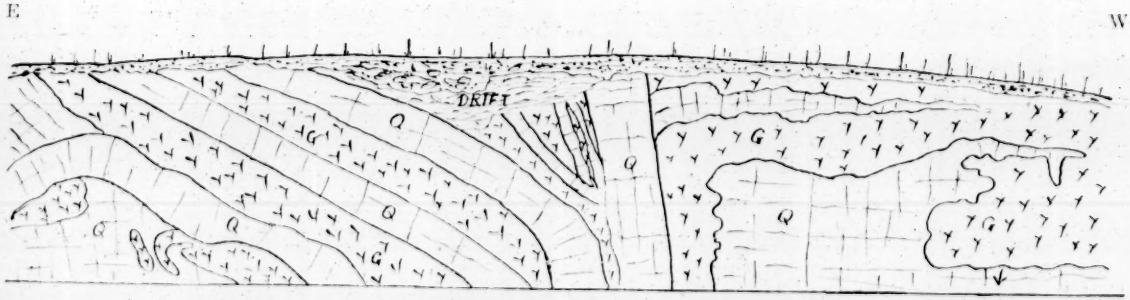


Fig. 2. Diagrammatized Section of quartz veins (Q) in granite (G) exposed in the Foxdale Silica Quarry. (See Map, Plate XVI.)

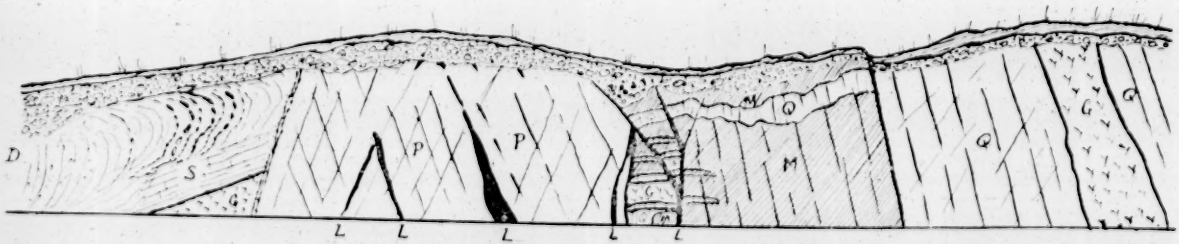


Fig. 3. Section in Eairy Quarry. (See Map, Plate XVI.)

Q. Quartz veins } including Harker's
P. Pegmatite } 'Greisen'.
M. Microgranite (with Dendrites).
G. Granite.
S. Slates (altered).
D. Glacial Drift.
L. Limonite in joints.

mineral. These quartz veins, as at Grainsgill, traverse the other types of rocks."[1] It is significant that here in the Skiddaw granite quartz-mica pegmatite and small quartz veins occur. The north-eastern trend-line of the Isle of Man strikes into the Lake District, and the Manx slates have been long supposed to be comparable with the Skiddaw slates.

Pegmatite is seen in the Eairy Quarry and marked 'pegmatite' on the diagram. Mr. Harker uses 'greisen' to denote a rock with felspar in subordinate amount, with a rather coarse-textured mosaic of quartz and the mica in moderately large flakes. No topaz or cassiterite are present. No felspar has been found in the quartz rocks in Eairy Quarry, but rocks consisting simply of a mosaic of quartz and mica are present and here are included among the pegmatite. In only one case was a pegmatite found with felspar. A block of large-grained pegmatite with quartz, muscovite, and kaolinized felspar was found near the Foxdale Silica Quarry, but not *in situ*. In the Eairy Quarry the coarseness of grain of the quartz rocks varies considerably. Some of the pegmatite is very coarse indeed, the quartz grains often too large to trace. In some cases the quartz consists of a mosaic with flakes of mica, and this may possibly correspond with Mr. Harker's 'greisen'. It should be added also that there is considerable evidence of dislocation and disturbance in this Eairy Quarry. Besides the limonite-filled joints, pressure effects are seen in the pegmatite, and in one case a large lenticle of quartz covered with a shining film of mica was found. The granite shows a tendency to foliation in thin section.

Mode of Origin of the Quartz Veins.

One cannot help speculating upon the possible ways by which these characteristic pegmatite and quartz rocks can have been formed. The veins of quartz occur, as seen, in the granite itself and also in the surrounding country rock. As far away as Fleshwick Bay, near Port Erin, on South Barrule and on Slieau Whaullian to the north-west, veins of quartz are found in the slates. These last, however, do not appear as dykes; they follow the cleavage of the slates in some cases, and in others cut obliquely across in strings and bands; sometimes they are in irregular lenticles. In Fleshwick Bay thick veins following the cleavage occur in the grits and slates seen there; the grit near the quartz veins is very much hardened by silicification. Here and on Slieau Whaullian sometimes the quartz veins occur in highly contorted slates, and the veins follow the intricate folds more or less closely. In these cases we have, it seems, water-formed veins—veins which have been formed by infiltration. On South Barrule both forms of quartz occur.

In the case of the veins in the granite, and of those 'dykes' of quartz in the country rock, the mode of formation seems to be in every way comparable with that of normal igneous rocks. Veins of aplite that occur in association with many of the acid plutonic rocks are often spoken of as representing the mother-liquor of the molten magma after the greater part has crystallized. In the normal

[1] "Grainsgill Greisen": Q.J.G.S., vol. li, pp. 143–4.

sequence of crystallization quartz is the final mineral to consolidate. We have seen from the quarry sections that the thick veins of quartz are not so regular as first supposed, and are usually inclined at angles with the vertical. It should be noticed also that sometimes the granite is veined and stringed with small quartz veins from ¼ to 3 or 4 inches in width. This is a local phase and occurs a little to the west of the summit of the hill. The evidence seems to warrant the idea that the veins of quartz represent the final consolidation product of the granite magma. If this is the case cooling must indeed have been slow to allow them to crystallize on such a large scale. The selvages found to some of the veins support this theory also. In one case there is a layer half an inch thick of mica in every way similar to the mica of the granite and of the pegmatite. In another case a lining of quartz and orthoclase felspar occurs as above described. It would seem that these linings are due to the mass of the molten silica with impurities being subjected to a process of segregation, the magma being mobile and the cooling so slow as to allow in the one case the mica and in the other the felspar to be separated and gathered together at the sides, and after an interval the silica to crystallize slowly. All the veins at present seen in the Foxdale Quarry show a very coarse structure, but, as stated, in the Eairy Quarry finer-grained quartz veins occur with also pegmatite. The quartz veins outside the granite are usually rather fine-grained.

At the point marked 'Aplite' on the Map (Plate XVI) a quartz rock of doubtful nature occurs. It resembles a dyke in its field relations, but the exposure is not good. It is associated with sheets 3 inches thick running in the slates parallel to the bedding, and though at first taken for a dyke it more probably is an altered grit faulted off on one side. In section it most resembles an impure quartzite.

There is a decided break between the consolidation of the plagioclase and the quartz, and the former occurs always in well-lamellated idiomorphic crystals. In a section of the granite from the Foxdale Silica Quarry all three felspars are present, and all the felspars as well as the muscovite include small fragments of quartz. The microcline is always interstitial. Garnet occurs in small irregular grains locally. Apatite is present, but not common. The rock is a soda granite with a rather high silica percentage. A good approximate analysis is as follows:—

SiO_2	72·5
Al_2O_3	16·3
Fe_2O_3	2·5
FeO	
MnO	
CaO	1·1
MgO	0·5
K_2O	3·2
Na_2O	3·2
TiO_2	0·2
P_2O_5	trace
Cl	trace
H_2O	0·54
	100·04

The granite contains plagioclase and microcline as well as a little orthoclase locally. The dominant mica is muscovite. The order of crystallization of the constituents is as follows:—

Muscovite.
Plagioclase (chiefly albite).
Orthoclase (when present).
Quartz.
Microcline.

The analysis shows the rock to be of a normal soda-granite type with a high silica percentage. The results compare fairly well with the analyses of granites of the Lake District and Ireland, except that aluminium is in higher percentage and the alkalis a little lower.

The condition of affairs seems to have been this—the main mass of the magma cooled to form the acid soda granite of which the analysis is given, but at the last there was a residuum of silica which crystallized out to form the peculiar quartz veins which run through the granite. The veins are igneous in origin, and there is no sign of 'comb' or other structure to suggest that water or vapours have helped in the formation.

Dendritic Markings in the Microgranite Dykes.

On Windy Common, about two miles south of the 'Granite Mountain', microgranite dykes occur with also a few quartz 'dykes'. The latter run north and south, but the former, of which seven could be mapped, all run north-east to south-west. Several of these 'elvans' have been quarried, and some are still being worked. In one of the most actively worked dykes peculiar dendritic markings occur. They were first noticed by Professor Boyd Dawkins, who kindly directed me to the locality and placed his specimens at my disposal. The dendritic markings are solid—not marks on one plane on the surface of the rock, but marks due to the actual soakage of solutions depositing oxides of iron in the rock. They always start on a joint plane, the sides of which are stained with the iron oxide, and run varying distances into the microgranite. Broken surfaces parallel to the joint plane give numerous circular dark marks, and sections at right angles to the joint planes give irregular marks, sometimes dendritic, sometimes almost straight. In section under the microscope the rock is seen to be a microgranite with quartz, felspar (plagioclase and orthoclase), and muscovite. The mica usually exhibits a tendency to parallelism and other evidence of pressure is not wanting. The staining in section is seen to be merely infiltered colouring matter between the grains. The dendritic marks can be wholly dissolved out of pieces of the rock by hydrochloric acid, yielding a yellow solution of ferric oxide and the fragments becoming quite white. As stated above, the dendrites occur also at Eairy Silica Quarry, and here also one gets the typical surface markings, properly dendritic in outline. Specimens of the dendritic microgranite are very striking and the usual character of the rock is hidden by the dark staining. It is a peculiar infiltration effect which seemed worthy of notice in this place.

IV.—Formation of a Laterite from a practically Quartz-free Diabase.

By Professor J. B. Harrison, C.M.G., M.A., F.G.S., F.I.C.

Part II. Microscopical Evidence.

THE chemical evidence with relation to the formation of a laterite from a diabase was given in a paper in the March number of the Geological Magazine, pp. 120–3. Since that account was written I have made microscopical examinations of the materials therein described.

Thin sections of the diabase and of its crusts of laterite were specially prepared for me by Messrs. Voigt and Hochgesang of Göttingen, the slices of the laterite being cut through both the inner buff-coloured layer and the outer red one.

Structure of the Diabase.—When seen under the microscope the diabase proves not to be as fine-grained as it appears to be in the hand-specimen. It is a moderately fine-grained ophitic diabase or dolerite, in which the pyroxene has some tendency towards an idiomorphic or in parts a granular structure. The pyroxene is a colourless augite of high double refringence; in a few places its masses are bordered by minute patches of a greenish biotite, some small flakes and aggregates of which also occur here and there in the rock. The felspar appears to be almost entirely labradorite, although there are a few patches of non-striated felspar which may consist of orthoclase; these patches show some slight strain effects. There are a few small interstitial patches of a micropegmatite of two felspars; I could not detect with any certainty any micropegmatite of felspar and quartz, but there may be some present. There are also a few minute interstitial patches of augite with some undifferentiated matter. Most of the labradorite is in the form of relatively long prisms which vary to a considerable extent in their breadths, some resembling in their sections broadish plates. There are some large, very irregularly shaped granules of titaniferous iron generally of ilmenite type, and these are very irregularly and unevenly scattered through the rock.

As an unimportant accessory constituent a few small granules of olivine are present, whilst some long and very narrow prisms or needles of zoisite, and exceedingly rarely a short prism of apatite occur. Careful search has been made for quartz, but only a very few minute interstitial grains of that mineral have been detected; these, however, appear to be of secondary origin.

Numerous measurements have been made of the minerals present in the slices, with the following results, given in percentages of the constituents of the diabase by weight:—

	Slice I.	Slice II.	Mean.
Felspar	48·6	50·1	49·35
Augite	41·5	44·4	42·95
Biotite	1·7	·6	1·15
Magnetite	7·0	4·8	5·9
Olivine	1·0	·2	·6
Quartz	·07	—	·04
	99·87	100·1	99·99

It is evident from the above that the augite of the diabase is either more calciferous than is shown by the calculation of the mineralogical composition of the rock from its chemical analysis given on p. 121 of this Magazine for March last, or else that I have not fully allowed in my measurements for the proportion of labradorite included in the ophitic areas of augite. The proportion of felspar found in the various series of measurements ranged from 44 to 50·5 per cent., those of augite from 44·1 to 44·8 per cent., of biotite from ·5 to 1·9 per cent., of olivine from nil to 1·0 per cent., whilst those of titaniferous iron-ore ranged from 4·7 to 13·7 per cent. The interstitial quartz detected varied from nil to ·08 per cent.

The slices have been most carefully searched for signs of incipient weathering. These are found to be more frequent and more marked in those parts of the slices which have been cut from the outer part of the diabase in contact with the crust of laterite than in the inner ones. The signs are far more marked in the felspar prisms than in the masses of augite. The few granules of olivine also show well-marked signs of incipient alteration along their cleavages.

I was not able to trace satisfactorily the changes along the cleavages and the lines of 'chemical weakness' of the felspar by the use under polarized light of ordinary microscopic objectives, although I used various powers up to and including a one-twelfth inch homogeneous immersion objective; but finally I succeeded in getting good results by the use of a Zeiss 4 mm. apochromatic objective with a No. 12 ocular, and possibly even more satisfactory ones using the same objective with a W. Watson and Sons' B analyser-eyepiece.

Among the weathering products present are a few scattered minute flakes of a chloritic nature; while the lines of chemical weakness and some of the cleavages in the plagioclase felspar are marked by very minute colourless scales and lamellæ of a mineral of somewhat higher refringence and distinctly higher birefringence than is the labradorite. These scales show a somewhat inclined extinction.

From their general properties the minute scales appear to be gibbsite or hydrargillite, a mineral which I have previously observed as a secondary product in some of the felspars of certain British Guiana rocks. I cannot detect any signs of carbonates in the slices. The weathering effects on the augite are more difficult to detect than are those in the labradorite. But along the cracks and cleavages of some of the augite masses there are minute scales similar in general character to those in the plagioclase, but which are of lower refringence and of somewhat lower birefringence than is the pyroxene; the major part, however, of the incipient weathering products in the augite are more or less opaque and are difficult or not possible to differentiate.

The Structure of the Laterite.—As already mentioned, the slices were cut through both the inner and the outer crusts of laterite so that it is possible to trace the changes and the differences in them. Under a low magnification the slices show very clearly the structure of the rock from which the laterite was formed, and this is far better marked in its inner than in its outer part. The former masses of augite are now occupied by reticulated intersecting lines and streaks of limonitic iron-ores which are of a more or less transparent

orange-yellow tinge in the inner parts, but change to brownish-red and red translucent masses, with in places more or less opaque patches, in the outer parts. The former areas of felspar are outlined along the junctions of the former prisms of felspar by films of limonite, and so are the former cleavages and the lines of chemical weakness. The spaces between the films of limonite are completely filled with glimmering masses or aggregates of very minute scales of gibbsite, which mineral can also be detected more sparsely and irregularly distributed between the ferruginous reticulations in the former augitic areas.

The higher powers of the microscope show in the part of the laterite adjacent to the unaltered diabase a few minute fragments of unaltered, not-stripped felspar, but these are of very sparing occurrence; some small areas of felspathic micropegmatite, in which one of the felspars is more or less clouded whilst the other remains clear and transparent; small irregular areas or blebs of secondary quartz are of rather frequent occurrence, especially in the immediate vicinity of patches of micropegmatite; occasionally, but rarely, quartz occurs in hexagonal blebs; a few long and very thin prisms of zoisite can be found, whilst here and there are seen small patches of more or less chloritized or bleached biotite. In this part of the lateritic crust the original iron-ores are little, if at all, changed. By far the greater part of the felspar is altered into aggregates of minute scales of gibbsite, the nature of this mineral having been proved by comparison with gibbsite in some slices of highly bauxitic laterite. Some of the augite masses appear to be changed into or replaced by limonitic products *en masse*, many of these strongly resembling goethite; other portions are altered into aggregates of talc stained with ferruginous matter, while in a few places some of the augite has been altered to a light-brown mica; a few fragments of unchanged augite remain. But the most usual alteration of the augite is into interlacing streaks of limonitic hydrates of iron with sparsely distributed patches of very minute scales of gibbsite between them. The latter may be a product from small crystals of labradorite included in the augite. In the middle and outer parts of the laterite slices no remnants of unaltered felspar or of micropegmatite can be found, while the prisms of zoisite are indicated merely as 'ghosts'; the talc and the secondary mica in the former augitic areas have disappeared and have been replaced by limonite or other hydrate of iron, and no remnants of unaltered augite remain. A few small patches of original mica still remain and are but little altered. The titaniferous iron-ore has undergone some changes, many of the granules showing evidence of having lost some of their magnetite, only the ilmenite remaining quite unchanged. The secondary iron-ores have in part segregated into aggregates which are generally of a reddish-brown to a red colour and in places are more or less opaque. Changes in the state of aggregation of the gibbsite are also indicated, many of the scaly aggregates showing rotating crosses under polarized light, and others show more marked concretionary structure, while in a few places the hydrate of alumina has assumed the form of angular platelets, some of which appear to be roughly hexagonal. Small granules of quartz exactly similar to those

in the inner part of the laterite are present in considerable number, but in these slices of laterite they do not appear as abundantly in the outer crust as they do in the inner one; this, however, may be due to differences in the distribution of micropegmatite in the original rock.

The microscopical studies have afforded important corroboratory evidence to that supplied by the chemical examinations. Like the latter they indicate that, at any rate in the case of a diabasic rock, the changes which result in the production of a laterite are exceedingly simple, and are such as would result from the mass-action of percolating rain and soil waters through very long periods of time. In the case of the felspar I cannot trace any production of hydrated micas or of kaolinite as intermediate between the plagioclase and the gibbsite. In that of the augite the change appears to be nearly but not quite as simple; in its case talc appears to be in part an intermediary product directly from the pyroxene, whilst a ferruginous mica seems to be a temporary product from the possible interaction of some of the constituents of the augite and of the orthoclase fraction of the felspars. The fact of the deposition of part of the silica set free by the weathering of the silicates in the form of more or less irregular granules of quartz is fully corroborated.

The comparisons of the inner and the outer parts of the lateritic crusts indicate that subsequent to the changes which gave rise to the laterite there were changes in the state of aggregation and of the hydration of the oxide of iron due doubtless to its solution and redeposition, whilst indications are not wanting that the gibbsite is subject, but to a lesser extent, to similar changes.

The examinations have thrown little light on the production of the masses of bauxitic laterite, in which much of the hydrate of alumina appears to be in a colloidal state.

V.—What is a Metamorphic Rock?

By Professor E. H. L. Schwarz, A.R.C.S., F.G.S., Rhodes University College, Grahamstown, South Africa.

THE latest book on metamorphism, Dr. V. Grubenmann's *Kristallinen Schiefer*, still leaves it an open question what a metamorphic rock is. Generally speaking there is no doubt about the matter; every geologist has a more or less precise idea of what he means by the term, but no one has yet been able to propound a definition which is perfectly satisfactory, and which will enable one to distinguish a metamorphic rock from all other kinds and at the same time convey an expression of the characteristic peculiarities inherent in such a rock. The need of a definition is very necessary. The want of it has led Dr. Grubenmann to include some rocks among the crystalline schists which one ordinarily would not refer to that class, and on the other hand there are some rocks frequently referred to that class which are not included. In the first case, the masses of emery form the twelfth group of Dr. Grubenmann's classification, yet the analysis of the Naxos emery, which reveals traces of boric oxide (1·15 per cent. in one case) would seem to place these lenses among the ore-bodies deposited by pneumatolitic action. In the second case, the granulites

appear to be genetically related to the eclogites and should find a place in a systematic classification of crystalline schists if the eclogites are included, whereas Dr. Grubenmann leaves them out though the eclogites are one of the rock-types included in his fourth group.

Van Hise logically defines a metamorphic rock as one that has been altered, and hence, as agents of metamorphism, we find listed plants, worms, burrowing animals, and man. One's dinner plate thus could be classed as a metamorphic rock, but it would be an unusual use of the term. There are conventional restrictions to such general terms, just as in the use of the word 'geology', which means the science of the world. If we were to apply Van Hise's logical use of terms, then we should mean by geology the science of everything on the earth and the *Encyclopædia Britannica* would be all too meagre a textbook. But while the old-fashioned expression 'mineral kingdom' usefully defines the subject-matter of geology, what are the restrictions that are to be observed in the use of the term 'metamorphic rock'? what is the subject-matter to be treated under metamorphism?

There is no doubt that the general usage is to exclude from metamorphism the change in rocks produced by weathering and also the change brought about by igneous fusion, whatever that expression means, so that we obtain an upper and a lower limit.

In the case of the upper limit, what amount of change is necessary in a rock for it to be taken from one of the other classes and placed in the metamorphic class? Certainly not the ordinary compacting of sediments, nor even the simple cementing of the grains by deposit from solution of silica, iron oxide or sulphide, calcite, etc., will make a sedimentary rock a metamorphic one; nor will the development of pegmatitic structure take an igneous rock out of its own particular class.

The development of secondary crystals in sedimentary or igneous rocks is again not sufficient to make a rock a metamorphic one. In the Carboniferous sandstones about Grahamstown the shaly laminæ are profusely scattered with scales of secondary mica (sericite), and these lie on perfectly unaltered Devonian shales; the sandstones have undergone a process of change precisely similar to that which produces a mica-schist, yet the micaceous sandstones are not metamorphic rocks. In the case of igneous rocks in the same way, diabases and melaphyres in which the augites, for instance, are entirely altered to uralite, are still igneous rocks, yet the process of alteration is the same as that which produces a hornblende-schist.

Dr. Grubenmann defines metamorphism as a process of rock-forming which is quite as characteristic as that which produces igneous or sedimentary rocks; it impresses on the crystalline schists their peculiar character and invests them with an independence as a class in contrast to other rocks. But what the 'stempel' or peculiar character is which, impressed on a rock, at once allows one to class it as a crystalline schist, Dr. Grubenmann does not say.

The crystalline schists, the same author says, are rocks which may have originated from igneous or sedimentary rocks, or mixtures of the two, in which the chemical composition has remained essentially

unaltered. Consequently rocks of the same composition, no matter what their origin, under the same conditions of metamorphism, yield the same variety of crystalline schist. That is to say, a sandy dolomite with a layer of salt on top to render sodium to the mass, will, under the action of metamorphism, produce a diorite gneiss just as readily as an original diorite of approximately the same composition. Still, the amount of alteration necessary to change the sedimentary or igneous rock into a metamorphic one is left unexpressed.

If we take Dr. Grubenmann's three types of metamorphic rocks we seem to be near the possibility of a definition; there are, according to this author, rocks of three types, those belonging to the uppermost, middle, and lowermost zones of metamorphism, the first being represented by the phyllites and chlorite schists, the second by the schists proper (mica-, hornblende-schists), and the third by the gneisses and eclogites. The zones are marked off by the action of pressure. In the uppermost zone the pressure is stress (mass × motion) or, as we might call it, dynamical pressure; in the lowermost zone the pressure approximates to hydrostatic pressure, or pressure acting equally in all directions, which we can call static pressure. Under the action of these forces hydro-chemical processes have gone on in the sense that in the uppermost zone the compounds formed obey the volume law, that is to say, are those with the smallest molecular volume; in the lowermost zone the activity of the molecules is such that they are enabled to overcome the pressure from without and form compounds independently of the volume law. Thus, an impure dolomite might yield in the respective zones—

Uppermost zone.		*Lowermost zone.*	
Garnet and quartz.	Molecular volume.	Augite and anorthite.	Molecular volume.
$Ca_2 Mg Al_2 Si_3 O_{12}$.	123	$Ca Mg Si_2 O_6$ . .	68·0
$Si O_2$	22·8	$Ca Al_2 Si_2 O_8$ . .	101·1
	145·8		169·1

Under extreme pressure, where static pressure is alone active, the crystals will form without any reference to direction, which is produced by dynamical pressure, hence the minerals in the crystalline schist will crystallize as in an igneous rock. Here we come to the difficulty in defining the lower limit of crystalline schists; for if it be true that an increasing disregard of the volume law is characteristic of the lower zones, then the igneous rocks become simply metamorphic rocks in one stage lower than Dr. Grubenmann's lowest zone, thus:—

Lowermost metamorphic zone.		*Igneous rock.*		
Eclogite.	Molecular volume.	Gabbro.		Molecular volume.
Garnet, $3 R_3 Al_2 Si_3 O_{12}$.	369	Augite	$\{2 Ca Mg Si_2 O_6 \mid Mg Al_2 Si O_6\}$.	204·0
Omphacite, $Na Al Si_2 O_6$.	64·8	Olivine, $Mg_2 Si O_4$ . .		43·9
Quartz, $2 Si O_2$ . .	45·6	Anorthite, $2 Ca Al_2 Si_2 O_8$.		202·2
		Albite, $Na Al Si_3 O_8$ . .		100·3
	479·4			550·4

It is very generally held now that igneous fusion of rocks is accomplished with the help of water; whatever rock we examine, whether it belongs to the acid series with micas which contain combined water, or to the basic rocks (perhaps with the exception of some of the ultra-basic rocks), there is always evidence that a part of the peculiarities exhibited by it must be explained by aqueous solution. Quartz is readily soluble in water at 200° C., and becomes a powerful acid like nitric or sulphuric acid; the solution becomes a solvent in which bases can be dissolved, and on cooling or supersaturation these would combine with the silica to form the various minerals of igneous rocks. The pegmatites and quartz veins which come from granite masses can be regarded as the end products of a series of crystallizations which began by the formation of the normal granite and which were accomplished by hydro-chemical processes. There is the old experiment of Fouqué and Michel-Lévy of fusing microcline and biotite; the melt on crystallizing gave leucite, olivine, and magnetite. If it be objected that the pressure on the earth's crust was the only thing needful to keep the chemical combination represented by microcline and biotite, we have Oetling's experiments to contradict such an assumption. Oetling,[1] on fusing the rock-forming minerals under pressure, found that the melt solidified as a glass, whereas under ordinary pressure they crystallized, sometimes as the original minerals, sometimes, as in Fouqué and Michel-Lévy's experiment, in other forms. Whichever way we attack the question we find that solvent-water is the agent active in forming the characteristic minerals and structures of igneous rocks: a discussion of the whole question, with references, is given in *Natural History of Igneous Rocks*, by A. Harker, pp. 294 et seq.

If this be so, then where are the dividing peculiarities between, say, a graphic granite and an eclogite? Both form dyke-like masses which may be in both cases in gneiss; both are holocrystalline with the crystals formed without reference to any leading direction, and more than one mineral may be common to both (quartz, felspar, hornblende, etc.), and yet the one is unquestionably a rock belonging to the so-called igneous class and the other to the metamorphic class. The answer seems to me to lie in a recognition that in the igneous rock some law of chemical combination has been carried out under circumstances which have allowed complete freedom of molecular action, whereas in the metamorphic rocks there have been restrictions. Using the fact that the sum of the molecular volumes of the minerals in an igneous rock are greater than the sum of the molecular volumes of corresponding minerals in a metamorphic rock of the same chemical composition, it is perhaps possible to define the differences in the two as due, in the one case, to the internal pressure (i.e. molecular activity) having been greater than the external pressure, and in the other that the reverse has obtained. In other words, if a rock magma is under sufficient pressure to allow the solid particles to move freely into the solvent water, the chemical affinities of the substances in the

[1] A. Oetling, "Vergleichende Experimente über Verfestigung geschmolzener Gesteinmassen unter erhohtem und normalem Druck": Tscher. Mitt., xvii, 1898.

magma are allowed to satisfy themselves without reference to any disturbing factor, and an igneous rock will result. If on the other hand the pressure is not sufficient to produce a complete fluidal phase, in Riecke's sense, but the whole rock remains solid except at the boundaries of the constituent grains where interchange of substance can take place, then the law of least molecular volume comes into play; the small amount of dissolved substance is restricted in its molecular activity, and a metamorphic rock is produced.[1] As the pressure approaches the static condition the mineral arrangement will tend to become massive like that of igneous rocks, and as the pressure decreases the lateral stress will produce more and more pronounced schistose structures.

If we accept some such definition of a metamorphic rock in terms of molecular energy we can apply it to separate such a rock at its upper limit, as well as at its lower limit, from other varieties. That is to say, a metamorphic rock must be one in which dynamical pressure has acted, and the term cannot be applied to one in which, owing to peculiar circumstances, a mineral usually associated with metamorphism has crystallized, as in the micaceous sandstones referred to above.

A metamorphic rock under this conception could not arise between two sedimentary rocks, or in the midst of an igneous mass, because the metamorphism, being due to hydro-chemical reactions under dynamical pressure, will be a measure of the 'head' or pressure on the water which permits the chemical activity to proceed. Water under such a pressure will permeate all the surrounding rocks irrespective of their texture or composition, and therefore there can be no selective action on particular zones of the rock-complex, but there will be a progressive intensity of metamorphism from above downwards. Mere accession of heat will not produce a metamorphic rock; for example, the anorthosites of Canada are traversed by bands of brecciation in which the rock is reduced to a 'Rutschmehl'; in Madras, in the charnockite gneisses, similar bands or 'trap-shotten' are produced in which the temperature has risen sufficiently to partially fuse the rock,[2] but these mylonites are entirely different from metamorphic rocks.

In the case of contact metamorphism the same explanation will simplify considerably the interpretation of the phenomena. Along the course of the dyke, or in the neighbourhood of the intruding boss or laccolite, the water pressure will be temporarily increased to such a degree that metamorphic action can proceed. If the 'head' of the water is maintained either by fresh supplies from the invading magma or by the closeness of the texture of the rock suddenly subjected to the increased water pressure, then metamorphic action will go on vigorously; if, however, the surrounding rocks are not sufficiently compact, or the invading rock is not pumping up sufficient water to

[1] E. Riecke, "Über das Gleichgewicht zwischen einem festen, homogen deformierten Körper und einer flüssigen Phase, insbesondere über die Depression des Schmelzpunktes durch Spannung": Nachr. Ges. Wiss. Göttingen, iv, p. 278, 1894.

[2] T. H. H. Holland, Mem. Geol. Surv. India, vol. xxviii, pt. ii, p. 198, 1900.

maintain the pressure, then the metamorphic action will not take place and a granite or dolerite may come to rest against a slate without showing the least sign of alteration at the contact.

The purpose of this note, however, is not to discuss the whole subject of metamorphism but to draw attention to the want of definitiveness in the terms used by authors in describing the metamorphic rocks. It seems to me to be impossible to attain any definitiveness unless we use molecular energy as a basis: the mischief of this is that it makes it necessary for geologists to add to their already overburdened subject the additional trouble of physical chemistry.

Addendum.—Since writing the above I have received *Recherches sur l'exhalaison volcanique*, by A. Brun, in which it is recorded that certain of the metamorphic minerals, kyanite, epidote, vesuvianite, etc., have their crystalline structure destroyed at temperatures in many cases much below the fusion-point. Epidote, for instance, loses its crystalline structure at 900° C. and fuses at 1250° C.

Epidote	$= 2\,H\,Ca_2\,(Al\,Fe)_3\,Si_3\,O_{13}$, molecular volume	296
Anorthite	$= 3\,Ca\,Al_2\,Si_2\,O_8$,, ,,	303·3

So that, in spite of its having within its molecular structure water, iron, and a surplus of lime, epidote has a far smaller bulk than the igneous mineral anorthite. The destruction of the crystalline structure by heat long before fusion seems to point, therefore, to expansion of the molecule. All the metamorphic minerals do not show this character, garnet and spinel for instance, but the presence in a rock of one mineral that does might be taken as an indication that the rock belongs to the metamorphic class.

VI.—On a large form of *Anthrapalæmon* from the Clay-ironstone Nodules of the Middle Coal-measures, Sparth Bottoms, Rochdale.

By Henry Woodward, LL.D., F.R.S.

As long ago as 1836 Prestwich published his historical paper "On the Geology of Coalbrook Dale",[1] and in it he figured a Crustacean carapace under the name of *Apus dubuis*.

In 1861[2] J. W. Salter figured and described some new Coal-measure forms of Crustacea which he referred to the genus *Anthrapalæmon*, gen. nov., and included therein Prestwich's *Apus dubuis*.

In my second year's Presidential Address to the Geological Society, in 1896, I dealt with the "Life-history of the Crustacea in Later Palæozoic and in Neozoic Times", and, under the Decapoda Macrura, I referred to those of the Coal-measures (Proc. Quart. Journ. Geol. Soc., 1896, vol. lii). "Eight species of *Anthrapalæmon* from the Coal-measures of Scotland and England, one from Illinois, U.S.A., and one from Nova Scotia, illustrate the abundance of these small Crustacea in the Carboniferous period. They have many points in common, but probably deserve more than specific differentiation.

[1] See Trans. Geol. Soc., 1840, vol. v.

[2] See Quart. Journ. Geol. Soc., vol. xvii. p. 530, 1861.

"With the exception of *Anthrapalæmon Parkii*, *A. Traquairii*, and *A. Etheridgei*, which measure from 3 to 5 inches, the other species do not exceed 1 to 2 inches in their entire length.

"The carapace and body-segments were evidently and usually broadly expanded, as in the ERYONIDÆ; the large scale at the base of the outer antennæ suggests the PENÆIDÆ; the strong basal joints of the inner pair of antennæ with bifid flagella, and the outer pair with single ones, are like many of the modern Caridea and Astacidea; the caudal appendages forcibly recall the rhipidina of the living Galatheidæ, in which, as in some ancient forms, there are two additional broad lamellæ to the tail-fan, developed one on either side of the telson.

"In the spinose ornamentation of the somites and caudal plates, in the broadening out of the segments of the abdomen and the short rounded form of the cephalo-thoracic shield in *Anthrapalæmon Parkii*, one is reminded of the genus *Squilla*, though probably this is only an analogy" (pp. xcviii, xcix).

I quote this last paragraph to show that, in 1896, I had a strong conviction that these forms from Eskdale, placed at that time under *Anthrapalæmon* by Dr. B. N. Peach,[1] deserved to be referred to a distinct genus, and a recent study of the rich materials from Glencartholm in the British Museum convinces me of the propriety of their subsequent separation by him.

Dr. B. N. Peach's original essay already referred to (see Trans. Roy. Soc. Edinb., vol. xxx, p. 73, 1882; p. 511, 1883) was followed, in 1908, by a most important memoir, published by the Geological Survey of Great Britain, entitled "A Monograph on the higher Crustacea of the Carboniferous Rocks of Scotland", 4to (issued October 28, 1908), pp. 82, pls. i–xiii, in which, in addition to the specimens figured in the previous work, he incorporated all the new material added to the Survey Collection between 1883 and 1905, and made a complete and very careful revision of the earlier work.

The species dealt with are placed under the following genera, namely:—

SCHIZOPODA.[2]	Group I. Mysid Group.	Lophogastridæ.	*Tealliocaris*, Peach, 1908, with 9 species and varieties.
			Pseudo-Galathea, Peach, 1883, with 3 species.
			Anthrapalæmon, Salter, 1861, with 2 species and varieties.
			Pygocephalus, Huxley, 1857, with 1 species.
		Perimecturidæ.	*Perimecturus*, Peach, 1908, with 7 species and variety.
		Anaspidæ.	*Palæocaris*, Meek & Worthen, 1868, with 2 species.
		Mysidæ.	*Palæmysis*, Peach, 1908, with 3 species.
	Group II. the Euphausid Group.	Euphausidæ.	*Anthracophausia*, Peach, 1908, with 3 species and varieties.
			Crangopsis, Salter, 1863, with 10 species.

[1] Dr. B. N. Peach, Trans. Roy. Soc. Edinb., vol. xxx, p. 73, 1882; p. 511, 1883.

[2] Without in any way desiring to detract from the great value and importance of Dr. Peach's monograph, it may be well to bear in mind the caution expressed by Dr. W. T. Calman in his review of Dr. Peach's memoir in the GEOLOGICAL MAGAZINE for 1909 (pp. 76–8) as regards the reference of all these forms to the

The following is a list of the species mentioned by Dr. Peach in his memoir[1]:—

TEALLIOCARIS, Peach, 1908.
Tealliocaris loudonensis, Peach, p. 9.[2]
T. Woodwardi (R. Eth., jun.), 18.
T. Woodwardi, var., 22.
T. Etheridgei (Peach), 22.
T. Etheridgei, var. *lata* (Peach), 23.
T. robusta, Peach, 24.
T. robusta, var. nov., 25.
T. tarrasiana, Peach, 26.
T. formosa, Peach, 27.

PSEUDO-GALATHEA, Peach, 1883.
Pseudo-Galathea macconochiei (R. Eth., jun.), 28.
P. rotunda, Peach, 28.
P. ornatissima, Peach, 29.

ANTHRAPALÆMON, Salter, 1861.
Anthrapalæmon Grossarti, Salter, syn. = *Russellianus*[3] (Salter), 30.
A. Russellianus, var. *spinulosus*, Peach, 36.

PYGOCEPHALUS, Huxley, 1857.
Pygocephalus Cooperi, Huxley, 37.

PERIMECTURUS, Peach, gen. nov., 1908.
Perimecturus Parki (Peach), 40.
P. Parki, var. *duplicicarinatus*, Peach, 41.
P. Stocki, Peach, 42.
P. elegans, Peach, 44.
P. communis, Peach, 47.
P. ensifer, Peach, 49.
P. Puttoni, Peach, 51.

PALÆOCARIS, Meek & Worthen, 1868.
Palæocaris scotica, Peach, 54.
P. Landsboroughi, Peach, 55.

PALÆMYSIS, Peach, 1908.
Palæmysis Dunlopi, Peach, 57.
P. Couttsi, Peach, 59.
P. tenuis, Peach, 60.

ANTHRACOPHAUSIA, Peach, 1908.
Anthracophausia dunsiana, Peach, 61.
A. dunsiana, var. *obesa*, Peach, 66.
A. Traquairi (Peach), 67.

CRANGOPSIS, Salter, 1863.
Crangopsis socialis, Salter, 69.
C. Rhodesi, Peach, 73.
C. magna, Peach, 75.
C. Couttsi, Peach, 76.
C. robusta, Peach, 78.
C. minuta, Peach, 80.
C. Eskdalensis (Peach), 80.
C. elegans (Peach), 81.
C. hastata, Peach, 82.
C. Huxleyi (H. Woodw.), 82.

Of the more characteristic forms of the genus *Anthrapalæmon*, as defined by J. W. Salter, met with in Illinois, U.S.A., in Nova Scotia, at Airdrie (Lanarkshire), Ipstone (North Staffordshire), Shropshire, and Lancashire, it may be stated that the carapace is nearly quadrangular, the frontal border being nearly straight, and only a fifth less broad than the widest part of the carapace at its centre; the abdominal segments are short, hardly longer than the cephalothorax, which is nearly as wide as the carapace itself. The median ridge is well marked, also the cervical furrow; the front angle of the carapace has a sharp spine, and the rostrum is strongly produced

Schizopoda, some of which at least had been believed to belong to the Decapoda. Dr. Calman also expressed a doubt as to the determination of some of the species referred to *Crangopsis* and to the Euphausidæ; but space does not permit us to deal with these divisions satisfactorily here.

[1] See Geol. Surv. Mem., *Palæontology, Higher Crustacea of Carboniferous Rocks of Scotland*, 1908, E. Stanford, London, 4to, p. 6.

[2] The pages given here refer to Dr. Peach's memoir.

[3] *Anthrapalæmon Grossarti*, Salter, was published in 1861 (see Q.J.G.S., vol. xvii, p. 528, with woodcut), *Palæocaridina Russellianus*, Salter, in 1863 (Q.J.G.S., vol. xix, p. 520, figs. 1 and 2). I pointed out in 1866 (Trans. Glasgow Geol. Soc., vol. ii, p. 246) that *A. Grossarti* and *P. Russellianus* were *identical species*, and as the former had two years priority over the latter, the name *P. Russellianus* must disappear and become a synonym of *A. Grossarti*, Salter; see also Brit. Mus. Cat. of Brit. Foss. Crustacea, 1877, p. 8.

and ridged. Subjoined is a list of American species referred to the genus *Anthrapalæmon*:—

Anthrapalæmon Hilliana, Dawson, 1877. Geol. Mag., Dec. II, Vol. IV, p. 56, Fig. 1. Coal-measures: South Joggins, Nova Scotia.
,, ,, Dawson, 1878. *Acadian Geology*, Supp., p. 55, fig. 10. Coal-measures: South Joggins, Nova Scotia.
,, *gracilis*, Meek & Worthen, 1865. Proc. Acad. Nat. Sci. Phil., vol. xvii, p. 50. Coal-measures: Mazon Creek, Grundy Co., Illinois.
,, ,, Meek & Worthen, 1866. Geol. Surv. Illinois, vol. ii, p. 407, pl. xxxii, figs. 4*a–c*; vol. iii, p. 554, figs. *a*, *b*.
,, ,, White, 1884. Thirteenth Report Dept. Geol. Nat. Hist. Indiana, p. 180, pl. xxxviii, figs. 8, 9.
,, ,, Packard, 1885. *American Naturalist*, vol. xix, p. 880.
,, ,, Packard, 1886. Mem. Nat. Acad. Sci., vol. iii, p. 135, pl. iv, figs. 1–3, 5, 6; pl. vii, figs. 3–6.

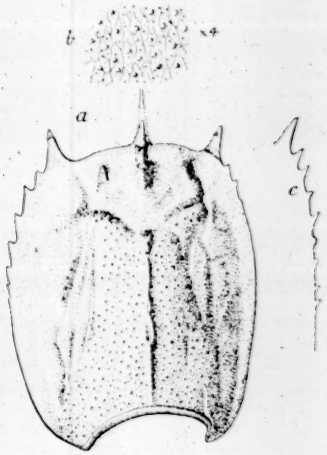
In 1905 I added a species of *Anthrapalæmon* (*A. serratus*) from the Lower Coal-measures, Colne, Lancashire (see Geol. Mag., Dec. V, Vol. II, pp. 438–9, Fig. 1), and another (either *Pygocephalus* or *Anthrapalæmon* (?) *Parkeri*, H. Woodw.) from the Coal-measures of Sparth, near Rochdale (see Geol. Mag., Dec. V, Vol. IV, p. 406, Fig. 2, 1907). I also gave a fuller account in 1907 (op. cit., pp. 400–7) of *Pygocephalus*, and figured and described the marsupial plates in the female of *P. Cooperi* (op. cit., Plate XVIII), not heretofore observed in a fossil Crustacean.

I am indebted to Mr. Fred Holt, of Rochdale, for the opportunity to figure and describe one of the largest specimens of an *Anthrapalæmon* from the Coal-measures I have yet seen. It was obtained from a concretion of clay-ironstone, on the reverse side of which several casts of Lamellibranch shells (*Carbonicola*, etc.) are exposed. Notwithstanding some irregular fractures the nodule exhibits on its upper surface the cephalo-thoracic shield of a Palinuroid, the contour of which, as well as the ornament on its dorsal region, is very well preserved (a thin crust-like cover represents the obverse of the cast which originally concealed the carapace from view).

Dimensions. Length of carapace, 42 mm.; greatest middle breadth, 36 mm.; breadth upon the front border of shield, 25 mm.; at posterior border, 20 mm.; the posterior border is strongly arched, rising 6 mm. at the centre on the dorsal line. The lateral borders are moderately expanded outwards, and the margin on either side is sharply serrated along the anterior half (Fig. 1*c*), ending in a prominent spine on the latero-anterior border. Inside the latero-anterior spines the frontal border is nearly straight or but slightly curved towards the rostrum, which is prominent and had one or more serrations on its basal portion. The dorsal ridge is prominent for 26 mm., when it is crossed by and subsides into the cervical furrow, which is strongly arched for 8 mm. on either side the dorsal line; it then bifurcates sharply anteriorly towards a submedian spine, and posteriorly to join a longitudinal furrow running obliquely to the posterior margin. The dorsal region of the carapace between these oblique longitudinal lines is ornamented

with minute tubercles and fine anastomosing lines (see Fig. 1*b*), one rather larger tubercle than the rest occupying each interspace between the lines.

When compared with the beautiful series of figures given in Dr. B. N. Peach's monograph of the *Higher Crustacea of the Carboniferous Rocks of Scotland*[1] we find no fewer than seven figures on plate iv devoted by Dr. Peach to the illustration of *Anthrapalæmon Grossarti* = *Russellianus* (Salter), the species to which our specimen (here figured) is most closely related.



1/1

FIG. 1. Carapace of *Anthrapalæmon Grossarti*=*Russellianus*, var. *Holti*. Coal-measures: Sparth, near Rochdale. Obtained by Mr. Fred Holt.

Of these,[1] figs. 1, 4, 6, 7 (pl. iv, op. cit.), being views of the carapace, offer the best illustrations for comparison with our Sparth specimen.

Fig. 2 shows a carapace, partly decorticated, but having its lateral border nearly entire, with about eighteen serrations along its margin and exposing wide sternites and row of plates with gills and other organs.

Fig. 3 gives a side-view of the same species, showing endopodites and exopodites of trunk-limbs and gills attached to their bases; the eyes, antennules, and antennæ with rounded scales at bases of same.

Fig. 4 gives an excellent profile of another carapace of this species with the rostrum and hepatic spines preserved.

Fig. 5 shows four segments of the abdomen with terminal lobe (pygidium) and pleopods partly preserved.

Fig. 6 represents a complete carapace with abdomen attached (slightly displaced), showing pygidium and pleopods preserved.

Fig. 7, like fig. 1, shows a detached carapace (*A. Russellianus*, var. *spinulosus*).

It will be observed that in figs. 1, 2, 4, and 7, in which the carapaces of *A. Grossarti*=*Russellianus* are drawn, Dr. Peach shows that the

[1] See Mem. Geol. Surv. Great Britain, *Palæontology*, 4to, Glasgow, 1908, in which his previous memoirs (Trans. Roy. Soc. Edinb., 1882 and 1883) are incorporated (pp. 82, pls. i–xii).

serrations on the sides extend the entire length of the lateral border and are strongly and regularly developed, and that the surface ornamentation in figs. 1, 2, 3, and 4 is strongly scabrous and devoid of the fine anastomosing lines observed in the Sparth carapace.

In Dr. Peach's fig. 6 the ornamentation appears somewhat less rugose, and the serrations are confined to the anterior half of the lateral border, as is the case in our Rochdale specimen. The two lateral spines, one on either side of the rostrum (in our example) in the centre of the hepatic region, seem to be replaced in the Scottish specimens by an oblique line of five very small serrations.

In the absence of appendages it will suffice to draw attention to this very large and interesting carapace, which no doubt belongs to the genus *Anthrapalæmon*; it is doubtful, however, if it should be erected into a new species. It may suffice at present to refer to it as *Anthrapalæmon Grossarti*, var. *Holti*, var. nov.

I should mention that in another concretion from Sparth, also obtained by Mr. Fred Holt, there are parts apparently of a second carapace of *Anthrapalæmon*, quite as large as the first already referred to, but more shattered in situ. The complete carapace has its own counterpart, but that has been broken in removing it to expose the relievo side, and has since been joined together again.

REVIEWS.

I.—The Coast Scenery of North Devon: being an Account of the Geological Features of the Coast-line extending from Porlock in Somerset to Boscastle in North Cornwall. By E. A. Newell Arber, M.A., F.L.S., F.G.S. 8vo; pp. xxiv, 261, with 64 plates, 2 maps, and 12 text-illustrations. London: J. M. Dent and Sons, Ltd., 1911. Price 10*s.* 6*d.* net.

(PLATE XVII.[1])

THIS is a handsome volume well printed in large type and profusely illustrated with pictorial and other views. As the author remarks, it is "intended to deal solely with the nature and origin of the coast scenery", and we may add that a more appropriate general title would have been "The Coast Scenery of North Devon and parts of West Somerset and Cornwall". With many parts of this coast from Porlock to Clovelly and again at Bude and Boscastle geologists are familiar, but no one before has made such a careful detailed study of the entire coast, and in particular of the "wildest and grandest cliffs" that extend between Hartland Point and Bude.

The author in his Introduction gives a general account of the geology and main topographical features. In dealing with the scenery the lithological characters of the formations in the Devonian and Carboniferous systems and their structural features are of prime importance, but lists of fossils are recorded in the course of the work, and the aid of Mr. Henry Woods in the difficult matter of nomenclature is acknowledged in reference to the Devonian species. Attention is called to the disputed age of the Morte Slates, but the author "is inclined to hold, provisionally, to the older theory that

[1] = plate ii in Mr. Arber's book.

Synclinal Fold to the north of Bude, Hartland District; being plate II of Mr. E. A. Newell Arber's book on *The Coast Scenery of North Devon*, reproduced by permission of the Publishers, Messrs. J. M. Dent and Sons, Ltd.

the apparent sequence is the real succession", and in his map he places the Slates at the top of the Middle Devonian, above the Ilfracombe Beds. The great series of Culm Measures is divided into Lower and Upper Carboniferous. The latter group, as Mr. Arber demonstrated in 1904,[1] includes representatives of the Lower and Middle Coal-measures; while the Lower Carboniferous, in the Boscastle District, consists chiefly of "black shales, with subordinate bands of sandstone and occasional deposits of Radiolarian cherts". The junction on the coast between Lower and Upper Carboniferous north of Boscastle is regarded as a thrust-plane, and no section of the junction is visible on the northern side of the basin near Appledore.

Much yet remains to be done in working out the detailed succession of the Upper Carboniferous rocks, and this has not been attempted by the author. What is wanted now is a detailed section along the coast, and the author has paved the way for the accomplishment of this great task. His work will be an invaluable guide to all geologists and others desirous of investigating the coast sections. It would be appropriate as a prize in educational establishments.

Some parts of the coast can only be safely reached by boat; some cliff-paths are dangerous in windy weather, and a number of them are but little used. The author, however, gives clear directions with regard to the best way to get to each district, noting the most suitable head-quarters in it, together with particulars of 6 inch and other maps; he likewise recommends three golden rules: "First of all, study the length of beach to be traversed on a large-scale map, and also, if possible, from the cliff-top before the attempt is made. Secondly, make sure of the tides beforehand; and thirdly, never venture alone." Rock-climbers, as he remarks, will find in the roughest portions of this coast "a new paradise", for "No words can convey the wildness and grandeur of these cliffs".

With these and other preparations the reader is taken from Porlock to Boscastle in six stages, the districts being divided as follows: (1) Lynton, (2) Ilfracombe, (3) Mortehoe, (4) Clovelly, (5) Hartland, and (6) Boscastle.

The author points out and shows in his excellent plates that there are two distinct types of cliff—(1) that of the Hog's-back, rounded hills sloping steeply towards the sea with but low cliffs, and often wooded to near the sea-level, as at Porlock, Lynton, Heddon's Mouth, and Mortehoe; and (2) the flat-topped cliffs, with nearly vertical faces, as at Clovelly, Hartland, and Boscastle. These are alike spoken of as "sea escarpments", but it is usual to confine the term escarpment to inland features. It is true that the Hog's-back features are in the main formed by subaerial denudation, like the inland ranges of Exmoor, and have been undercut when brought under the action of the sea. On the other hand, the flat-topped cliffs "are the product of sea erosion on an elevated, flat, or gently sloping tableland", and have no connexion with subaerial escarpments.

With regard to the main outlines of the coast the author points out that there are no special reasons connected with exceptional hardness of the rocks to account for the headlands of the Foreland and of

[1] Phil. Trans., ser. B, vol. 197, p. 291.

Hartland Point; their forms are due rather to the topographical features of the land prior to the influence of the sea.

This was the view taken by Mr. Clement Reid in reference to Hartland Point in his Memorandum on the Coast Erosion of Cornwall and North Devon.[1] In fact, more information on sea-coast erosion has been published than the author appears to realize, from the time of De la Beche's *Geological Observer* to that of the *Sea-Coast* by Mr. W. H. Wheeler (1902), and the Reports of the Royal Commission on Coast Erosion, which contain a bibliography of the subject by Mr. Whitaker.

To the minor features along the coast, all of them full of interest and many of them never before described, the author has given special attention. From Hartland to Boscastle and in other tracts, where to judge from a small-scale map the indentations appear to be few, there are many small promontories and little bays, some caused by the relative hardness of the rocks, some by master-joints, faults, and thrusts, aided by streams. The dislocations and contortions in the Culm Measures are extraordinary in their abundance and variety, and many striking pictures and diagrams are given by the author. Plate ii—our Plate XVII[2]—which we reproduce by the courtesy of the Publishers, represents some of the bolder features. Nor has it been easy to get photographs on a coast where the difficulties of access are great and the breadth of shore but little: here the author expresses his obligations to Mr. D. G. Lillie, who contributes a sketch-map of the drainage of the country, and specially aided the author in his observations on the waterfalls.

No less than seventy-seven streams, flowing to the coast mostly from short distances inland, are shown on the map. "While the larger streams and rivers have been able to work faster at lowering the inclination of their valleys at their mouths than the marine erosion has been able to cut back the cliff, yet the smaller streams, possessing less power of eroding their beds, have worked at a relatively slower rate than the sea, and consequently end in hanging waters or coastal falls." Waterfalls in all stages are thus to be observed, and the influence exerted by the local inclinations and flexures in the strata, the initiation of canyons, and the features in the streams that flow off the Hog's-backs and flat-topped hills all receive attention.

Reference is made to the Raised Beaches of Baggy Point and Saunton, to the later Submerged Forests of Porlock and Westward Ho!, and to the influence of the movements on the coast-line, on the one hand in the separation of the Woolacombe cliff-line from the sea, and on the other hand in the drowning of certain river-valleys. The author regards a sandy beach as "a sure sign of a senile wave platform". Perhaps it would have been better to say that "senile wave platforms" are characterized by sandy beaches, the instances given being at Woolacombe, Croyde, Widemouth, and Braunton Burrows, where the supply of new materials eroded from the cliffs has ceased.

[1] Appendix, No. xii, B, p. 170, Report Royal Commission on Coast Erosion, vol. i, pt. ii, 1907.

[2] Plate ii (our Plate XVII), "Synclinal Fold to the North of Bude, Hartland District" (p. 7).

The travelling of shingle and the influence of shingle in the destruction of the cliffs by the breakers are dealt with, but we question the statement (p. 199) that "the greatest amount of erosion is off the points, where not only the waves are largest, but their transported load of debris is heavier and more powerful as an erosive factor". The author remarks that there the water is deepest. Mr. Reid in his evidence given before the Royal Commission (before noted) explains that in the case of some Cornish headlands the points may remain after the harder rock, which was the cause of the headland, had disappeared, as such points descend into deep water, which in stormy times would not be charged with the sand and pebbles that occur in the bays. Nor can we agree with the author (p. 36) that the waters of the Bristol Channel "have naturally little power of erosion even in times of storm". A visit to the coast near Watchet would not support this view. Nevertheless, we may fully agree with him that along the hard rocky coasts which he describes the changes that have taken place "within the memory of the oldest generation" are for the most part inappreciable. If, however, the destruction along the coast is not so serious as that along the borders of our eastern counties, the infinite variety of rock-structures, the grand scenery described with enthusiasm by the author, and the various processes of erosion now in action, form a far more interesting field of study.

II.—Barrande's Silurian System of Bohemia.

Système Silurien du Centre de la Bohême. Par Joachim Barrande. 1e partie: Recherches Paléontologiques. Continuation éditée par le Musée Bohéme. Vol. IV: Gastéropodes, par le Doct. Jaroslav Perner. Tome III. 1911. Traduit par A. S. Oudin. Pls. 176–247.

SOME account of the scope of this great work was given in the Geological Magazine for March, 1908, together with a brief abstract of the contents of the first two 'tomes', and an explanation of the difficulties encountered and so ably overcome by Dr. Perner.

Now we have tome iii before us, which maintains in every respect the high standard of its predecessors. Dr. Perner expected that in addition to the material on the Gasteropoda originally collected this volume would also have contained all that has since come to light on the subject, as well as descriptions of the organisms other than Gasteropoda figured on the plates. This he has, however, found impossible, hence there is still a supplement to follow.

Tome iii contains the descriptions of members of seven families, viz., the Capulidæ, Naticidæ, Horiostomidæ, Calyptræidæ, Siphonariidæ, Atlantidæ, and the Pterotracheidæ: numerous figures of these are now given in addition to those already published, as well as figures of some fifty forms previously described. It also comprises comprehensive and exhaustive tables showing the distribution of all the forms dealt with, together with remarks on their genetic affinities, the nature of the sediments in which they are embedded, and their representatives in other countries. Valuable Addenda and Corrigenda to the three 'tomes' are also given.

Considering the divergence of opinion among authors with regard to the relationship and classification of recent mollusca of which they have complete representatives, it is not surprising that they should differ when they are dealing with the imperfect remains of past ages. Thus palæontologists are at variance as to the genera they include in the Capulidæ, Cuv., as some of the forms referred to it approach the Naticidæ and others the Neritidæ. Perner places in that family the following six Bohemian genera, containing 188 species and extending from E–e 1, to G–g 3: *Platyceras*, Conrad; *Orthonychia*, Hall; *Platyostoma*, Conrad; *Strophostylus*, Hall; *Cirropsis*, Pern.; and *Naticonema*, Pern. Perner separates from the Tertiary and recent genus *Capulus*, Montf., Palæozoic forms greatly resembling it, and groups them in the genus *Platyceras*, Conrad (*Acroculia*, Phill.). This genus is limited to shells distinctly spirally coiled, while *Orthonychia*, Hall, is reserved for those forming a straight cone whose apex is simply or slightly curved on the same plane. The number of forms belonging to these two genera is immense; Barrande's MS. enumerates 400 species, which are represented on 150 plates, more than half the number of species intended for the three 'tomes' of vol. iv. Since his time specimens have accumulated, and in the midst of such wealth of material it has been difficult to decide on the limits of a species, for a considerable extent of variation exists on the one hand, while on the other there are strong connecting links. Though not reducing the number of species to such a degree as Lindström does for Gotlandic forms, Perner yet brings them down to 98 for *Platyceras*, of which 96 are new, and 45 for *Orthonychia*, of which 41 are new. There are besides numerous varieties and some doubtful species not included in the above numbers. *Platyceras* is most abundant in the Silurian (E), while the greater number of *Orthonychia* occur in the *Devonian* (F–f 2), generally in the condition of internal moulds. Dr. Perner finds it convenient to divide these two genera into groups of species, each associated with a characteristic form.

Naticonema, Pern., is distinguished by its flat, discoidal shape, without umbilicus, slightly thickened inner lip with thin, vertical lamella, and by its longitudinal prominent scaly striæ. *N. similare*, Barr., the only Bohemian species, is the genotype. It comprises, in addition to his *Otospira squamata*,[1] shells referred by Barrande to no less than seven different species belonging to six distinct genera. Amongst foreign forms Dr. Perner would place in this genus some specimens figured by Lindström as *Platyceras cornutum*. His *Naticonema* is confined to E–e 2.

Cirropsis, Pern., comprises more elongated shells with the general appearance of *Holopea*. They are distinguished by their loosely coiled whorls, oblique and unthickened aperture, and by the direction and nature of their transverse ornamentation. Numerous species were described by Barrande in MS., and referred by him to *Cirrus*. These are reduced by Perner to five, and are shown to differ from *Cirrus* in the form of the aperture and ornamentation. This genus occurs in E–e 1, and e 2 (Sil.), and is represented both in Gotland and America.

[1] Spelt by Perner *squammata*.

Perner prefers retaining the name *Platyostoma*, Conrad, to adopting Fischer's *Diaphorostoma*, which he suggested on account of the name *Platystoma* having been previously used, and he considers the difference in spelling sufficient distinction without reference to the derivation of the word. The seven species included in this genus were with one exception (*P. ferrigenum*, Pern.) described by Barrande, and were generally placed by him in *Natica* or *Naticella*. This has the widest range in time of any of the genera of the Capulidæ, occurring in D–l 4, E-e 2, and G–g 1.

Five species are referred to *Strophostylus*, Hall, all but one of which were previously included in *Natica* or *Prænatica* by Barrande. The genus certainly bears a superficial resemblance to *Natica*, while on the other hand it has features in common with *Platyceras*. *S. gregarius*, Barr., the first species quoted, is shown to be very variable, and to compri-e several forms considered distinct species by other authors, but regarded by Dr. Perner merely as well-marked varieties, with numerous intermediate links, of which an ample series of figures is given. These species occur in E–e 1, F–f 1, f 2, and G–g 1.

The relationship of some of the members of the Naticidæ, Forbes, is not altogether clear. Some authors would place *Strophostylus* and *Platyostoma* here, but Perner, as already shown, considers these genera more closely allied to the Capulidæ. In the Naticidæ he places *Naticella*, Münster, the new genera *Himantonia*, Pern., and *Prosigaretus*, Pern., as well as the sinistral *Scævogyra*, Whitfield, with its new sub-genus *Versispira*, Pern., and the new genera *Lævogyra*, Pern., and *Antispira*, Pern.

A new sub-genus, *Naticellina*, Pern., is suggested for a species resembling *Naticella* in the character of the aperture, but differing in its form and spiral ornamentation, which are more like *Vanicoro*, Quoy & Gaimard. *N. suavis*, Barr., from E–e 2 is the genotype.

Himantonia, Pern., is represented by two species whose imperfect state of preservation does not admit of a diagnosis sufficiently well-defined to associate any foreign form with them, though the characters observable show them to be distinct from the members of any previously described genera. In ornamentation they resemble *Prosigaretus*, but their shape is distinct. The genotype is *H. amœna*, Barr. Both species occur in F–f 2.

Prosigaretus, Pern., resembles the Tertiary and recent *Sigaretus* in the form of the mouth, but differs in being ornamented with undulating and ramified grooves. The only species, *P. perornatus*, Barr., is the genotype, and it is represented by one imperfect specimen from F–f 1.

Versispira, Pern., is given as a sub-genus of *Scævogyra*, Whitf., from which it is distinguished by the section of the whorls being reniform instead of sub-triangular, and the aperture is probably of different shape. There are four species.

Lævogyra, Pern., is also sinistral, and possesses rounded, flattened whorls having an elliptical section and ornamentation consisting of strong transverse ribs. There is but one specimen known.

Antispira, Pern., the other sinistral genus, is proposed for a single badly preserved specimen with the general form of the Naticidæ.

It has, however, very distinctive ornamentation, consisting of strong transverse ridges crossed obliquely by spiral ones, which give rise to oblong tubercles at the points of crossing. All the species of the last three genera are from Étage D (Ordovician).

In the family Horiostomidæ, Koken, there are recorded four genera, *Horiostoma*, Mun.-Chalm., *Tubina*, Barr., *Meandrella*, Pern., and *Spirina*, Kayser. The genus *Horiostoma* is separated from *Poleumita*, Clarke (*Polytropis*, De Kon.), with which it has generally been identified, and is distinguished by having the umbilicus surrounded by a keel, by the rapid increase of the whorls, by the last one being often free, and by its trapezoidal aperture without operculum. It is represented by two species.

Tubina, Barr., is closely related to *Horiostoma*, and is chiefly distinguished by having the aperture enlarged like a trumpet, and by being symmetrically coiled. Three species are described.

Meandrella is created for a species (*Euomphalus sculptus*, Quenst.) greatly resembling *Tubina*, but differing in the ornamentation being less developed, in having zigzag transverse lines and in having the aperture less enlarged. The species belonging to the last three genera occur in F–f 2.

The fourteen species of *Spirina* described are all confined to Étage E–e 1, and e 2, with the exception of one which is also represented in F–f 1.

The family Calyptræidæ, Koken, in addition to the genus *Clisospira*, Billings, comprises two new genera of Perner, *Paragalerus* and *Procrucibulum*. The former is represented by a single species and greatly resembles *Progalerus*, Holzapfel, but is distinguished by its convex whorls, deep sutures, and ornamentation.

Procrucibulum contains three species, having a likeness to the genus *Crucibulum*, Schumacher, but which differ in the length and in the spiral form of their lamellæ.

We now come to the description of the genus *Hercynella*, Kayser (*Pilidion*, Barr. MS.), whose affinities have given rise to considerable diversity of opinion, authors referring it respectively to the Siphonariidæ, Fissurellidæ, Auriculidæ, or the Capulidæ. The chief requisite for deciding this question is the discovery of well-defined muscular impressions, and hitherto little of this nature has been observed by Dr. Perner. He places *Hercynella* in the first-named family, though its habits, according to him, must have been very different from other members of the group. It is especially characteristic of F–f 1, where it is represented by eight species. He states that the argillaceous and calcareous schists in which it occurs were deposited in warm seas of little or medium depth, and that they were certainly not of littoral origin. On this supposition, and taking also into account the thinness of the test, he suggests that it lived a pelagic life. As evidence in favour of its being a pulmonate he quotes that the fold of the shell varies in position in the same species, being sometimes dextral and at others sinistral, and he compares this with the case of certain species of *Helix* which may be either dextrally or sinistrally coiled.

Now the recent *Siphonaria* and its near ally, *Gadinia*, are eminently sedentary, being attached to rocks in the littoral zone, the former at or

above high-water mark, and the latter in the zone between high and low water. Their characters are generally regarded as transitional, and many authors would place them in the Opisthobranchiata rather than in the Pulmonata. A full consideration of all the circumstances renders it probable that the true relationship of *Hereguella* should be sought elsewhere. Dr. Perner divides them into two groups, one having low shells with a wide and but slightly raised fold, the other composed of conical forms with a very prominent fold. Fifteen species are recorded ranging from E–e 2, to G–g 3.

The last order to be treated is the Heteropoda, Lam., to which Dr. Perner refers two genera, *Porcellia*, Léveillé, and *Procarinaria*, gen. nov.; the former to the family Atlantidæ, and the latter to the Pterotracheidæ. He enters into minute particulars about the structure of *Porcellia*, and gives his reasons for differing from other authors in the position he assigns it. It is represented by six species, all from E–e 2, with the exception of *P. aberrans*, Koken (*P. bohemica*, Barr. MS.), which is from F–f 2.

Procarinaria is created by Dr. Perner for the reception of a single species from E–e 1. It is distinguished by a very small, compressed shell whose aperture is slightly notched in the middle, and the keel is solid and narrow.

The description of species being thus completed, tables giving their ranges follow.

In Table i we have the genera arranged *alphabetically*, with their synonymy, the species they comprise, their vertical distribution, and references to their descriptions and figures.

Table ii shows the vertical distribution of the genera arranged *zoologically*, with the number of species and particulars about their recurrence.

Table iii contains the genera arranged alphabetically, with their horizons and number of species.

Table iv gives similar information for the families.

Table v enumerates the genera and species occurring in each 'Bande' into which the 'Étages' are subdivided.

The author's critical analysis of these tables gives the general results of his long labours and merits the closest attention. The total number of species recorded is 719, of which 41 recur at different horizons, they are comprised in 157 genera and 22 families. As might be expected, the smallest number occurs in C (Cambrian), there being but one family, the Patellidæ, with one genus containing two species. There is a considerable increase in Étage D, which has 29 genera comprising 69 species.

E–e 2 contains the greatest number of species, viz. 406 referable to 103 genera.

E–e 1 has only 97 species included in 23 genera.

F–f 1 shows a still further decrease, having only 11 genera containing 16 species.

F–f 2 comes next to E–e 2 in numbers, having 147 species in 64 genera.

In G the amount of Gasteropoda decreases greatly, so that there are only 13 genera with 19 species.

With regard to duration Dr. Perner divides the genera into two series, viz.:—

A. Those which are confined to only one 'bande', of which there are 95.

B. Those which exist in more than two contiguous 'bandes', whose number is only 7.

Ten genera are more especially remarkable for their longevity, viz., *Carinariopsis*, *Clisospira*, *Cyrtolites*, *Euryzone*, *Hercynella*, *Palæacmæa*, *Loxonema*, *Platyostoma*, *Turbonitella*, and *Ectomaria*. The four genera *Bembexia*, *Calloconus*, *Mourlonia*, and *Trochonema* are peculiar for their manner of reappearing after long periods of absence. This is an instructive instance of the imperfection of the record.

E–e 1, and e 2, are especially closely connected, having nineteen genera in common; but there is an appreciable break between e 1 and D, for they have only one genus in common. There is also a decided break between F–f 1 and f 2, which is both palæontological and petrographical; only five genera are common to both divisions. F–f 1 is very poor in fossils, while f 2 is remarkably rich and has thirty-four genera in common with E–e 2. G–g 1 has only seven genera in common with F–f 2.

The nature of the matrix is in a great measure accountable for the abundance of fossils in E–e 2 and F–f 2, as the rock is for the most part calcareous.

The greater number of species also occur in a single 'bande', there being but thirty-nine species common to two contiguous 'bandes' (E–e 1, and e 2), and only two species appearing in both E–e 2 and F–f 2. The reappearance of species in succeeding 'bandes' only attains about 6 per cent. of the total number of species, and most of these are confined to E–e 1, e 2, and F–f 1 (Sil.).

Thus, owing to their less frequent recurrence, Dr. Perner regards the Bohemian Gasteropoda as of even greater service in the determination of the age of horizons than the Trilobites, Cephalopods, and Brachiopods.

A chapter is devoted to genetic relationships, but Dr. Perner does not consider our knowledge of genera, especially of those from foreign localities, sufficient for accurate deductions.

A list of twenty-nine species common to Bohemia and other countries is given, but this likewise cannot be looked upon as absolutely correct on account of the imperfection of the figures and descriptions hitherto published in most countries. Only four—two Silurian and two Devonian—are identified with British species, and it is very doubtful if the two former are conspecific.

Dr. Perner also gives a table of species from other countries, greatly resembling, though not identical with, Bohemian ones.

The immense importance of the work seems to justify the details entered into here, which, after all, give but a mere outline, the limits of space rendering it impossible to give more. The value of such a treatise to students of Palæozoic palæontology is apparent, and they must all feel deeply indebted to Dr. Perner for this painstaking and laborious contribution to science.

Jane Longstaff (Donald).

III.—Royal Commission on Coast Erosion and Afforestation.

Third (and Final) Report of the Royal Commission appointed to inquire into and report upon certain questions affecting Coast Erosion, the Reclamation of Tidal Lands, and Afforestation in the United Kingdom. 1911. Price 3*s*.

In the Geological Magazine for January, 1908 (p. 34), we drew attention to the First Report, and accompanying Minutes of Evidence, of this Royal Commission. The terms of reference of the Commission were afterwards extended to take in Afforestation, and the Second Report, dealing with that subject, was published in 1909. It includes a short account of the nature and extent of land suitable for sylviculture, and deals more particularly with methods of culture, labour, and administration; the Commission consider "that there are roughly 9,000,000 acres of land in the United Kingdom which may with advantage to the State be afforested".

The Third Report gives a summary of the evidence to which we referred in our former article, together with the principal conclusions and recommendations. The changes in the relative level of land and sea are first dealt with, and to the question "whether movements of a similar nature are likely to recur, and if so, when", it is remarked that no answer can be given. Mention, however, is made of slight submergences possibly in progress on the Northumberland coast, in the north of Scotland, and on the south and west of Ireland. The amount of erosion and accretion along the coasts is considered. It is admitted that erosion takes place below sea-level, and that "fine gravel had been found in suspension in the English Channel at 4 fathoms above the sea-bed in a depth of 37 fathoms"; but to what depth the movement of detritus on the sea-floor is effective in eroding is a question "on which further investigation is needed". The accumulation of shingle at Dungeness (the largest in the kingdom) is attributed to the supply of pebbles from the Sussex coast to the westward, "the shingle having travelled along the shore and down to the level where the waves influence the travel in deep water."

There is much valuable information about the derivation and distribution of beach deposits, and it is remarked "that while the beach material should not be removed from any part of the coast where it acts as a protective agency, erosion must continue at some places in order that a supply of fresh material may be furnished to replace that which is ultimately worn away".

Descriptions are given of the reclamation of alluvial flats and salt-marshes, of the protection afforded by Blown Sands, and of the aid given by various plants in the accretion of mud-flats and in the checking of wind-drifted material. There is an excellent description of the main geological features of the British coast-lines, and this is followed by an account of the erosion and accretion that is taking place. The general results are that while "on the one hand considerable areas of agricultural land are lost, sea-coast towns are injured, and harbours tend to silt up, on the other, large areas of valuable agricultural land are gained, and these areas on the average are more valuable than those which are lost". The gain has been

almost entirely in tidal estuaries, the loss on the open coast. In most cases the provision to protect agricultural land bordered by sea-cliffs that are formed of easily eroded strata "would involve a cost far in excess of the value of the land". Along some parts of the eastern coast, notably in Suffolk, the erosion has been intermittent, intervals of a series of years attended by little or no encroachment having occurred. The condition of Southwold, which has suffered grievously, has during the past few years improved by the construction of a north pier and by a harbour of refuge, so that the beach deposits are accumulating.

Descriptions are given of various engineering works for the protection of coasts, and recommendations are made with regard to the control of the foreshore, it being held "that a clear right of passage by foot upon all foreshores in the United Kingdom, whether Crown property or not, should be conferred upon the public". Recommendations are also made with regard to the further areas that might be reclaimed, and to loans of money for sea-defence purposes; but the Commissioners do not support the contention that sea-defence is a national service.

H. B. W.

IV.—Geology and Agriculture.

A Report on the Agriculture and Soils of Kent, Surrey, and Sussex. By A. D. Hall, M.A., F.R.S., Director of the Rothamsted Experimental Station, and E. J. Russell, D.Sc. Published by the Board of Agriculture and Fisheries, London. 8vo, cloth; pp. viii, 206, with 56 illustrations. Price 2*s.* 6*d.*

NINE years ago there was published a First Report on the Soils of Kent and Surrey, by Mr. Hall, who was then Principal of the South-Eastern Agricultural College, Wye, and Mr. F. J. Plymen. The main results at that time achieved are embodied with certain necessary revisions, and with an account of the soils and agriculture of Sussex; and the treatment of the whole subject, or series of subjects, is amplified and presented in a masterly manner in the volume before us.

To the geologist the Report is of exceptional interest, and it may be safely regarded as the most important volume published in this country on the bearing of geological science on agriculture. Half a century ago the practical advantages of a knowledge of geology to the farmer were not so apparent as they now are. Indeed, they were not to be discerned in many areas, for as S. V. Wood, jun., remarked in 1865, in reference to the eastern and midland areas, the observer was "often baffled by the highly fictitious representation given in every Geological Map". The fact is the Glacial Drifts, which may be from a few feet to more than 200 feet in thickness, were omitted from the maps, and they were not only useless but misleading from an agricultural point of view.

Since that date the Geological Survey has recognized the importance of mapping all the superficial deposits, and the surveys of the subsoils, which have been made on the 6 inch scale, form a sound basis for the more detailed agricultural investigation of the soils. Unfortunately the geological maps of large areas of England, notably in the counties

of Gloucester, Hereford, Shropshire, Worcester, and Warwick, remain in the 'fictitious' condition.

In the First Report, before mentioned, it was stated that "The geological map of the country furnishes the only possible basis for a classification and survey of its soils, at any rate, as far as the preliminary work goes". In the present work Mr. Hall observes (p. iv), "It will be seen that we have taken the geological formations as the basis of our work, and have assumed that each formation represented in the district will give rise to a soil-type which can be characterised both by its mechanical analysis and by special features in the farming which prevails over its outcrop. The justification for these cardinal assumptions was obtained in the early stages of the work by following the dividing line representing the outcrop of two formations, and finding (1) that the dividing line held for the soils as well as for the underlying formations; (2) that the soils from any formation (with one or two exceptions) did show on analysis certain common features which marked them off from other soils. These conclusions have been strengthened as our work proceeded; all our experience in the field goes to show that each formation in the area under consideration gives rise to a distinct soil-type, the characteristic composition of which can further be recognised by making up an average from the mechanical analyses of the samples taken from that formation."

Allowances, of course, have to be made in all cases for wind-drifted or other adventitious material in the soil, and for downwash on slopes. The above quotation, however, shows the importance of a careful detailed geological (or subsoil) survey.

The Geological Survey has indeed done more for the district than Mr. Hall appears to know, as new series 1 inch Drift maps, Nos. 317 (Chichester and Midhurst), 332 (Bognor, Selsey, and Littlehampton), 333 (Worthing and Rottingdean), and 334 (Newhaven and Eastbourne), have been published, and manuscript copies of 6 inch maps of the areas have been deposited for public reference in the Library of the Museum of Practical Geology.

It is therefore all the more remarkable that the results obtained by careful soil-investigation over areas represented for the most part by the older Drift maps of the Geological Survey have led to conclusions which we are justified in considering as far-reaching.

Similar results were notified in the Vale of Belvoir and bordering tracts by Mr. G. W. Lamplugh,[1] who had the advantage of some discussion on the ground with Mr. Hall and Professor T. H. Middleton. There it was found that "The geological boundaries conform fairly well to the varied character of the soils and subsoils, though the margins of the superficial deposits are rarely so sharply defined as the lines necessarily drawn for their delimitation on the map might seem to imply". We have dwelt at length on these matters because it may now be considered as demonstrated that a careful detailed geological map of all the exposed formations (Drift and Solid) is of essential service to the agriculturist.

[1] *Geology of the Melton Mowbray District, etc.* (Mem. Geol. Surv., 1909), p. 99.

The volume before us is divided into six chapters, dealing with the Natural Features; Agriculture; Soils on different formations, with methods of analysis; Relation of Soils to Crops; Building Stones and other Economic Products; and Analyses of Soils. There is also a bibliography and capital index. The illustrations are numerous and include orographic and geological maps, map of rainfall, maps showing the distribution of arable, grass, and wood lands, of crops (cereals, roots, hops, fruit, etc.), and of the distribution of cattle. There are pictorial views of the features of the Wealden, Lower Greensand, Chalk, and other formations, and Romney Marsh. There are pictures of oxen, sheep, and pigs, of hop-kilns, and of charcoal-burning. The illustrations, indeed, give an idea of the many subjects discussed, and of topics that will interest not only landowners and farmers, but geologists, geographers, and general readers, for there are many historical references to the state of the country in old times.

H. B. W.

V.—Brief Notices.

1. Cambrian Geology and Palæontology.—Dr. C. D. Walcott continues the publication of his researches on these subjects (Smithsonian Misc. Collections, vol. lvii, Nos. 2, 3, and 4, 1911). In No. 2 he deals with the "Middle Cambrian Merostomata", describing a new sub-order of the Eurypterida, to which he gives the name Limulava; a new family Sidneyidæ, and a new genus *Sidneyia* named after his son Sidney S. Walcott, who discovered the type-specimens in the Stephen formation in British Columbia. The species is named *S. inexpectans*. Another new genus from the same locality and horizon is named after Dr. H. M. Ami, *Amiella ornata*, and it is remarked that a second species of this genus or a closely allied form occurs in the Lower Cambrian of Yunnan in Indo-China.

In No. 3 Dr. Walcott describes certain "Middle Cambrian Holothurians and Medusæ", and in No. 4 he describes some Cambrian Brachiopods, Mollusca, and Trilobites from China, being his third preliminary contribution on the "Cambrian Faunas of China". It is anticipated that the full memoir on the subject will be published this year.

2. Moldavites or Tektites.—In a paper "On the supposed origin of the Moldavites and like sporadic glasses from various sources" (Proc. U.S. Nat. Museum, vol. xl, p. 481, 1911) Mr. G. P. Merrill considers that there is no proof that the specimens, which Suess has included under the name 'tektites', had a cosmic origin. He observes that "Whatever may have been their original source, the Bohemian and Moravian specimens are now simply water-worn pebbles of weathered glass, originally etched by corroding vapours or solutions, the results being indistinguishable from those produced by artificial etchings on obsidian with fluorhydric acid".

3. Lessons on Soil. By E. J. Russell, D.Sc. (1911, pp. xv, 132; price 1*s.* 6*d.*).—This is the first volume of a "Nature Study Series" in course of publication by the Cambridge University Press. It is an elementary work, admirably clear and concise, the main object of

which is to teach the composition and characters of soils and subsoils by means of practical experiments. A list of necessary apparatus is given, and the materials for examination should as far as possible be obtained locally. The experiments are adapted to explain porosity and permeability, the formation of springs, the shrinkage and expansion of clay, the action of lime on certain soils, the temperature of the soil, and the food and growth of plants. The origin of soils in general, of leaf-mould and peat, the action of worms and micro-organisms are discussed, and observations are made on tillage and drainage, on the aspect of the land and the influence of man. It might be mentioned (p. 1) that ground that is hard in dry weather and sticky in wet weather is not necessarily clay, as such conditions may be found on Chalk tracts. Reference is made (p. 22) to "the foolish man who built his house upon sand"; but this is rightly qualified (pp. 24 and 30) inasmuch as "people prefer to live on a sandy soil rather than on a clay", and the desirable conditions are shown in diagram (fig. 17). The view of "Landslip *in the Isle of Wight*" (fig. 6) should be "at Lyme Regis".

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

June 14, 1911.—Professor W. W. Watts, Sc.D., M.Sc., F.R.S., President, in the Chair.

The following communications were read:—

1. "On a Monchiquite Intrusion in the Old Red Sandstone of Monmouthshire." By Professor William S. Boulton, B.Sc., Assoc.R.S.C., F.G.S.

The paper describes a hitherto unrecorded monchiquite, intruded into the Upper Old Red formation of Monmouthshire, about midway between Chepstow and Usk. The precise manner of its intrusion is doubtful; reasons are given for regarding it either as a dyke with a north-westerly trend or as a volcanic plug (bysmalith). The disturbance and metamorphism of the contact-rocks (seen only at its eastern edge) are dealt with, as also the rounded lumps of marl and subangular blocks and chips of sandstone incorporated in the igneous rock.

The monchiquite, which is described in detail, contains unusually large phenocrysts (measuring up to 5 and 6 inches) of augite (chrome-diopside) and biotite, generally much corroded. Rounded lumps or 'nodules' of olivine-augite rock with chromite are also included, the olivine now being represented by secondary products, including iddingsite. A second generation of purple idiomorphic augite, biotite, and decomposed olivine occurs porphyritically in the ground-mass, with occasional granules of quartz and chromite.

The ground-mass is a felt of minute elongated augite prisms, magnetite grains, and flakes of biotite, and the remaining space is occupied by analcite enclosing apatite needles. Reasons are adduced for regarding the analcite of the ground-mass as primary. Ocelli filled with secondary carbonate, chlorite, analcite, etc., are common.

A complete analysis of the rock is given, which bears out the petrographical evidence that it is a very basic lamprophyre belonging to the monchiquite group. It is compared with other rocks of the group, and in particular with the monchiquites and camptonites of Colonsay, with which it has many points in common. Finally, its age and possible connexion with the only other known intrusion into the Old Red Sandstone of the South Wales area—that of Bartestree, near Hereford—are referred to.

2. "Notes on the Culm of South Devon: Part I—Exeter District." By Frederick George Collins, F.G.S.; with a Report on the Plant-remains by E. A. Newell Arber, M.A., F.G.S., and Notes on the Cephalopoda, by George C. Crick, Assoc.R.S.M., F.G.S.

The object of this paper is to show that the fauna of the Culm Measures of South Devon proves these beds to be the equivalents of the Pendleside Series of the Midlands, as has been shown by Dr. Wheelton Hind to be the case with the Culm Measures of North Devon. The area from which these fossils have come may be roughly described as a narrow strip of country 17 miles long, running from south-west to north-east, having the city of Exeter as its centre. The work has extended over ten years, and innumerable sections have been examined without result. The actual fossiliferous localities are eighteen in number, but often the fossils are too poor for determination. Plant-remains are abundant, but determinable specimens very rare; the preservation of the fragments is often excellent, although the fragments themselves are insufficient for specific determination. Such fossils as have been determined show a sequence from below upwards as we go from south to north; but it seems advisable to seek more evidence, and an attempt will be made by working due north from Waddon Barton, a point farther to the west, when, if the attempt is successful, another communication will be offered to the Society.

II.—Linnean Society.

June 1, 1911.—Dr. D. H. Scott, F.R.S., President, in the Chair.

Dr. A. Smith Woodward, F.R.S., read a paper on "The Fauna of the Carboniferous Period, so far as it has been discovered in the same deposits as the Carboniferous flora".

The fauna agrees with the flora in consisting, for the most part, of highly specialized representatives of the lower groups, but is singularly modern in some respects. Some of the freshwater and land mollusca are scarcely distinguishable from genera still existing. All the Crustaceans are of primitive groups, and some of the most interesting are related to *Anaspides*, which still survives in Tasmania. The myriapods, scorpions, and spiders are similar to those of later date, but a few of the scorpions retain obvious remnants of the characters of their aquatic ancestors. Limuloids also occur. Insects are numerous, but all belong to the lower groups in which there is no complete metamorphosis; and there are many generalized types which can scarcely be referred to existing orders. Cockroaches are numerous, but have transparent fore-wings. Primitive dragon-flies occur, and some of these are the largest known insects, with a span of wings

measuring 2 feet. Among fishes, the spiny acanthodian sharks, which are typically Lower Palæozoic, are still found in the Carboniferous fauna, and are known to have been preyed upon by the higher fishes. The pleuracanth sharks are characteristic of the period, and interesting as showing a more generalized vertebrate skeleton than any later fishes. The cochliodont sharks with grinding teeth appear to be closely related to the existing *Cestracion*, but have many of the teeth fused into extensive plates. Some of the sharp-toothed sharks also seem to have had their teeth fused into rigid masses. The highest fishes are the palæoniscids and platysomids, which exhibit all the fundamental characters of the present-day sturgeons, obscured beneath a normal covering of ganoid head-plates and scales. Large dipnoan fishes are numerous, and differ little from *Ceratodus*, except in showing traces of the separate points of which their dental plates are composed. Most important are the crossopterygian fishes, of which *Rhizodus* and *Megalichthys* are typical genera. These fishes make a closer approach to the earliest lung-breathers than any fishes which have existed before or since. Lung-breathers were certainly in existence just before the beginning of the Carboniferous period, and all seem to belong to a very primitive group of Amphibia, variously termed Stegocephalia or Labyrinthodontia in allusion to the complete roofing of their cheeks by bone and to the complicated structure of their teeth. In their possession of supra-temporal plates and often of post-temporal bones, as also in the marking of their superficial bones by the course of the slime-canals, these amphibians more closely resemble fishes than any later members of the order. Towards the end of the Carboniferous period some of the smaller Stegocephalia, the so-called Microsauria, seem to have passed into true reptiles very similar to the surviving *Sphenodon* or *Hatteria*.

III.—The South Staffordshire and Warwickshire Institute of Mining Engineers.

At the meeting on June 12, 1911, at the Council House, Walsall, a paper "On the Carboniferous Limestone of Fair Oak, Cannock Chase Coalfield", was read by Mr. George M. Cockin.

The rocks underlying the Coal-measures of the Cannock Chase Coalfield have been described as being Silurian Limestone. The condition existing at Walsall, where the Silurian rocks may be seen immediately below the Coal-measures, was supposed to continue further north, and this was said to be the case at a bore-hole at No. 2 Pit, Cannock Chase Collieries.

A few years ago fresh light was thrown upon the subject by the discovery of fossils belonging to the Lower Carboniferous or Mountain Limestone upon the old spoil-heaps of No. 1 Trial Pit, Fair Oak Colliery. The discovery formed the subject of a paper read before the Geological Society of London in 1906.[1]

A number of new fossils have been found since that date, and it is

[1] "On the Occurrence of Limestone of the Lower Carboniferous Series in the Cannock Chase portion of the South Staffordshire Coalfield," by George Marmaduke Cockin, Quart. Jour. Geol. Soc., vol. lxii, p. 523, 1906.

chiefly with the object of having a complete list of these published that the present paper is written.

The fossils have been named by Dr. Wheelton Hind, F.G.S., and Dr. Arthur Vaughan, F.G.S. Both these geologists have made a special study of the Lower Carboniferous Limestone, the former having established the position of an important group of rocks occurring at the very top of the series, and named by him the "Pendleside Rocks"; while to Dr. Vaughan is due the systematic grouping into definite zones of the whole of the Lower Carboniferous Limestone rocks. Dr. Vaughan based his work upon a thorough exploration of the fossils contained in the well-known section in the Avon Gorge, near Bristol, the result being a complete chart of the whole series, named the "Avonian Sequence". By means of this chart any collection of fossils belonging to the Lower Carboniferous may be recognized, and their particular position may be assigned in that sequence.

Dr. Vaughan, who examined the fossils found at Fair Oak, had referred them to the top of the Avonian fauna. The following is a list of the fossils determined:—

BRACHIOPODA.

Athyris planosulcata, Phil.
Chonetes laguessiana, de Kon.
Ch. gibberula, M'Coy.
Ch. sp.
Orthotetes crenistria, Phil.
Productus giganteus, Martin.
P. longispinus, Sow.
P. punctatus, Martin.
P. semireticulatus, Martin.
P. hemisphericus (senile form), J. de Sow.
Reticularis lineata.
Rhipidomella michelini, Léveillé.
Rh. divaricata, M'Coy.
Seminula ambigua, Sow.
Spirifer planicostatus, M'Coy.
Spiriferina cristata, Schlotheim.
Sp. mimima, Sow.
Schizophoria sp.

CEPHALOPODA.

A fragment.

CORALS.

Amplexi zaphrentis, Vaughan.
Millepora rhombifera, Phil.

CRINOIDEA.

Stem-joints.

GASTEROPODA.

Platyschisma.

ECHINOIDEA.

Archæocidaris urei, Fleming.

LAMELLIBRANCHIATA.

Parallelodon sp.

FISH-REMAINS.

Scales and teeth.

The trial-shaft at No. 1 Fair Oak commenced in January, 1872, passed through 286 feet of Bunter Sandstones and Gravels, set in an excessively hard calcareous conglomerate.

A remarkable feature in these beds was the occurrence of copper- and lead-ores in considerable quantities. These ores are, the writer believes, common enough in Keuper Sandstones, but are rarely met with in Bunter Conglomerates.

At a depth of 29 feet from the surface lead-ore occurred in large quantities, disseminated freely among the gravel, and continued down to a depth of 85 feet. At a depth of 75 feet from the surface copper-ore first showed itself, quite separate from the lead.[1] Lower down both ores were found mixed together in large quantities. At the base

[1] See "Copper and Lead Ores in the Bunter", by W. Molyneux, GEOL. MAG., Vol. X, No. 1, 1873.

of the conglomerates 750 gallons per minute of water were tubbed back. Passing through a thick bed of Red Marls, with hæmatite nodules, the shaft was continued down through shales, sandstones, ironstone bands, and clays to a depth of 813 feet, but no workable seam of coal was found. Below this a bore-hole 1¾ inches in diameter was continued in Coal-measure shales and sandstones to a depth of 975 feet. A feeder of salt water was met with at 960 feet, and a little lower a feeder of fresh water, together amounting to about 70 gallons per minute.[1]

Before abandoning the undertaking it was decided to search for coal by driving headings in the Coal-measures. Accordingly, at some distance above the bottom of the shaft, a heading was driven for 44 yards on the full dip of the measures, and from it headings were driven for nearly 150 yards at right angles on the strike. All operations were suspended on December 1, 1875, four years from the commencement.

It must have been in one of the exploring headings that the Carboniferous Limestone was found, because its position on the spoil-bank shows it to have been the last material deposited there before the place was abandoned.

After having lain undisturbed and exposed to the elements for nearly forty years, it was discovered by Mr. George Wetherall, of Rugeley, seven years ago, and he with the writer made a thorough search, with the results now described. The limestone lying exposed for so long a time has weathered away, and left the fossils very clearly defined. In no instance is there any appearance of the limestone being water-worn, and those pieces which were covered up have all the appearance of having been blasted out of the mine.

The section of strata passed through explains why the search for coal at this spot ended in failure; indeed, it would be difficult to find a better illustration than this affords of the immense amount of denudation to which the Coal-measures were subject, either previous to or at the time when the Bunter Conglomerates were laid down.

The marls and clays of Cannock and Wimblebury, etc., indicate that originally the Upper Coal-measures were present over some portion, at any rate, of the coalfield. Not only, however, have nearly all traces of these Upper Coal-measures been lost, but the productive Coal-measures themselves have in places been almost entirely removed.

It is quite certain that from whatever direction the great water-borne mass of conglomerate came in Triassic times, the coalfield on which it rested was of very irregular shape. The Fair Oak trial-pit proves that at that spot all the Coal-measures to an horizon below the Deep Coal Seam were denuded.

The area of this denudation is not of large extent: its limit on the south was proved by an exploring heading driven from a shaft sunk by the South Staffordshire Waterworks Company, while on the north-east the shallow coal-workings in Brereton Coppice Colliery have proved the position for an extent of over 1,000 yards.

The 'wash-out', as it is locally called, probably owes its existence

[1] See *Mining Journal*, p. 192, 1876.

to an anticlinal elevation, and while this elevated mass caused an obstacle which was no barrier to the mighty flood that removed it, it at the same time caused the limestone to be raised up to the position that it now occupies. The occurrence of the limestone must owe its existence either to a rapid thinning out of the lower beds of the Coal-measures or to its having been raised in the way suggested.

The great Carboniferous Limestone formation of Derbyshire probably thins out gradually southwards, until only a few feet of the upper beds are left. To quote Professor Bonney, in his remarks on the Fair Oak Limestone—

"About 22 miles to the east, the Carboniferous Limestone appeared to thin out on the north side of Charnwood Forest; it was doing the same thing near Wellington, about 47 miles to the west . . . over a semicircular district of which Fair Oak was the centre. He thought that the discovery marked a point in the southern shore-line of the northern sea-basin, perhaps a bay: thus resembling the limestone on the Titterstone Clee Hills, which must occupy a similar position on the northern shore-line of the southern basin."[1]

The collection of Carboniferous Limestone fossils from this pit were then handed over by Messrs. Cockin and Wetherall to the Institute for preservation and future reference.

MISCELLANEOUS.

British Museum (Natural History) Department of Geology.

Cainozoic Freshwater and Lacustrine Mollusca from Germany.—The extraordinary richness of the collections of the British Museum has rarely been better illustrated than by the table-case of German Cainozoic Mollusca just arranged and exhibited in the Geological Department by Mr. R. B. Newton with the assistance of Mr. G. K. Gude. The accumulation of nearly a hundred years, we have a fine series of the land, freshwater, and lacustrine shells which lived in Germany from Oligocene to Post-Pliocene times exhibited to our notice for the first time. No such series is to be found in any Continental museum with which we are acquainted. Many of the specimens come from localities now closed or inaccessible, and such well-known places as Cannstadt, Heinheim, Oeningen, Mosbach, Budenheim, Floersheim, Mainz, Wangen, Weimar, Taubach, Hochheim, Wiesbaden, and a score of others are represented in the collection. Similar series of Mollusca from the other Continental areas are in course of arrangement, the French and Austro-Hungarian being already in hand.

The Collections of the Geological Society of London.—In accordance with the resolutions passed on June 14 that the collections of the Geological Society should be divided between the British Museum and Jermyn Street, it is interesting to note that the Foreign Series has already been removed to its new home at the British Museum (Nat. Hist.), is all in order in new cabinets, and can be referred to by responsible students.

Bristol Museum.—Mr. Herbert Bolton, F.G.S., curator of the Bristol Museum of Natural History, has been appointed reader in palæontology in the University of Bristol.

[1] Quart. Jour. Geol. Soc., vol. lxii, p. 528, 1906.